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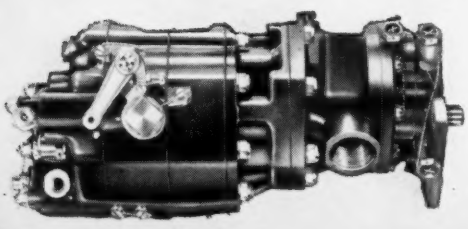

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AERONAUTICAL ENGINEERING REVIEW

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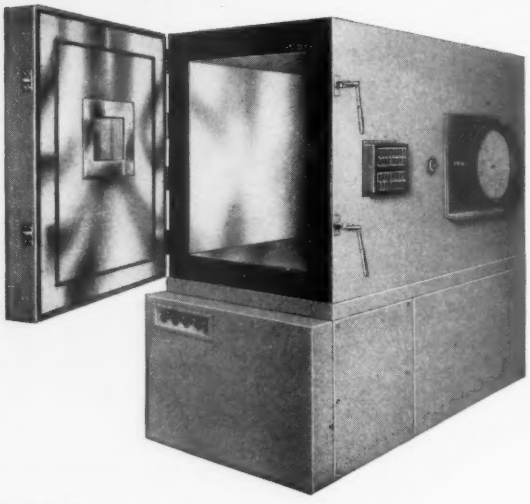

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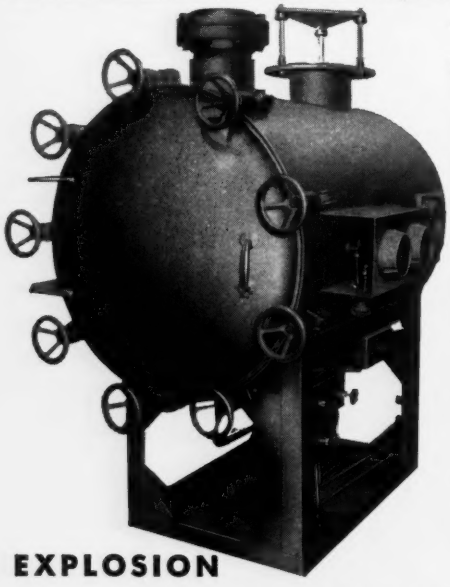

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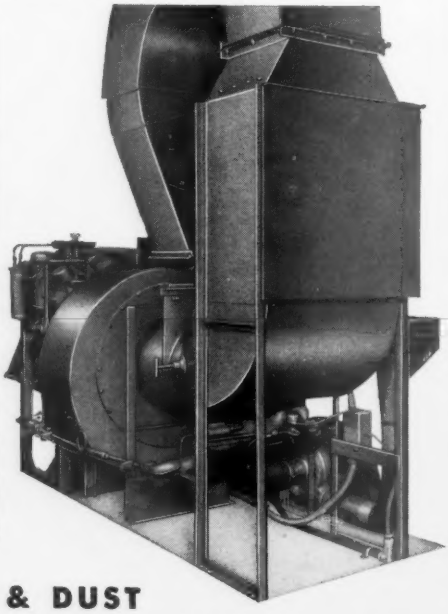

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I. A. S. News

A Record of People and Events of Interest to Institute Members

Flight Propulsion Meeting Marked Success

Over 600 Security-Cleared Persons Register for Technical Sessions. Reception, Dinner, and Exhibition by Local Manufacturers Social Highlights of Meeting.

E. W. ("Pop") Cleveland and Lewis Rodert, Chairman and Program Chairman, respectively, of the I.A.S. Cleveland-Akron Section.

FOR THE SECOND consecutive year, the Annual Flight Propulsion Meeting, held in Cleveland, was a security-closed meeting. All papers and discussions were classified "Confidential." Although no report on the technical sessions or publication of the papers can be made here, it is no breach of security to say that this seventh in this series of annual propulsion meetings was the largest and one of the most successful ever held. Five hundred and twenty-nine security-cleared persons, representing the "tops" among the country's aircraft propulsion experts, attended the technical sessions.

▸ **Reception and Exhibits**—An exhibit of aircraft products and a cocktail party, sponsored by nine local manufacturers, followed the technical sessions and added a further note of interest and sociability to the meeting. Hosts on this occasion were: American Steel & Wire, Cleveland Pneumatic Tool, Jack & Heintz, B. F. Goodrich, Parker Appliance, Pesco Products, Romec Division of Lear, Thompson Products, and Tinnerman Products companies.

▸ **Dinner**—The dinner, held in the ballroom of the Hotel Carter, was open to all I.A.S. members and guests. Approximately 400 people were on hand to enjoy the clowning of "mystery guest" Vincent Barnett, the inimitable toastmastering of "Pop" Cleveland, and an excellent dinner speech on Korea by Major Gen. L. C. Craigie. The full text of General Craigie's talk, "The Air War in Korea," will be published in the June issue of the AERONAUTICAL ENGINEERING REVIEW.

Much credit for the success and value of this meeting goes to the Cleveland Section's enthusiastic chairman, "Pop" Cleveland, and its hard-working program chairman, "Lew" Rodert. With the usual fine cooperation of N.A.C.A.'s Lewis Flight Propulsion Laboratory staff and personnel and the support of the Air Force on security, the entire program was extremely well-planned and executed.

W. A. S.

L. D. Gardner Receives M.I.T. Award

Major Lester D. Gardner, I.A.S. Fellow and Benefactor, was presented with the recently established Silver Stein Award by Dr. James R. Killian, Jr., President of Massachusetts Institute of Technology, at the February 15 dinner of the M.I.T. Club of New York. This award, which is believed to be the first presentation to an alumnus for services to M.I.T. or the M.I.T. Club of New York, bears the inscription: "Lester D. Gardner '98 whose devoted labors over the years have contributed immeasurably to the interests and welfare of Massachusetts Institute of Technology and M.I.T. Club of New York."

The Silver Stein Award will henceforth be given annually by the club "to a past or present member who has made an outstanding contribution to the club or to the [Massachusetts] Institute [of Technology] . . . and who by his consistent activities over a period of time has furthered the interests of and welfare of the club and the [Massachusetts] Institute [of Technology]."

Major Gardner, organizer and founder of the Institute of the Aeronautical Sciences, guided the affairs of the Institute from its founding in 1932 until his retirement 6 years ago. During his years with the I.A.S., he served first as Secretary, but in later years he was elected to the posts of Executive Vice-President and Chairman of the Council. At one time, Major Gardner owned and published several magazines, among them being *Aviation*, which he founded in 1916 and sold in 1928.

The New York Times

Drinks a Toast: *Major Lester D. Gardner (left) prepares to drink a toast from the Silver Stein that had just been awarded to him by Dr. James R. Killian, Jr. (right).*

I.A.S. Corporate Members Win Safety Contest

Three Corporate Members of the Institute won the first three places in a safety contest conducted during 1951 by the National Safety Council among companies in the aeronautical industry.

The first place winner was North American Aviation, Inc., of Downey, Calif. The Fort Worth Division of Consolidated Vultee Aircraft Company won second place, while AiResearch Manufacturing Company, of Los Angeles, made third place.

North American received a trophy as first-place winner. The winners of second and third places received certificates from the National Safety Council.

Supersonic Tunnel at Brooklyn

Dr. Nicholas J. Hoff, A.F.I.A.S., Head, Department of Aeronautical Engineering, Polytechnic Institute of Brooklyn, recently announced that a supersonic wind tunnel capable of speeds up to Mach 5 is now in operation there.

This new tunnel was completely designed by Dr. Paul A. Libby, M.I.A.S., Associate Professor of Aeronautical Engineering, and Dr. Antonio Ferri, A.F.I.A.S., Professor of Aerodynamics at Brooklyn Polytechnic. The testing of designs in the tunnel is being carried out under Government contract and for the industry.

Air Safety Awards Presented

The first annual "Captain Video Air Safety Awards" were presented at the Wings Club luncheon on February 27 by Al Hodge, who portrays Captain Video on the DuMont television network.

Among the recipients were: Flight Safety Foundation, represented by its Director, Jerome Lederer, F.I.A.S.; Charles Adler, Jr., Consulting Engineer—Aircraft Lighting; and Gill Robb Wilson, M.I.A.S., Editor and Publisher, *Flying* magazine.

Flight Safety was cited "for constantly striving through the industry and public service to improve air safety." Mr. Adler received the award "for his energy in attacking the problem of mid-air collisions; his inventions include: aircraft proximity indicator, studded reflector tail light, and his most recent invention which will be in use shortly, the silvered bulb fuselage light." Mr. Wilson's citation read: "for his continual efforts to truthfully and accurately interpret and disseminate aviation information in simple and direct language for all to understand."

These awards were created as a means of setting an example for millions of youngsters who are the future pilots and passengers and of giving them a better understanding of aviation and the allied sciences.

News of Members

▸ **Dr. H. Roxbee Cox** (F.), Chief Scientist, Ministry of Fuel and Power, Great Britain, was the recipient of the James Clayton Prize for 1951. This award, which carries with it an honorarium of £1,550, was presented to him on February 15 by the Institution of Mechanical Engineers (Great Britain) for "his contributions to engineering science and practice, particularly in the fields of aeronautics, power generation and fuel utilization, communicated in part in a Thomas Hawksley Lecture to the Institution in November, 1951."

▸ **Dr. Kenneth S. M. Davidson** (F.), Director, Experimental Towing Tank, Stevens Institute of Technology, was named by the Society of Naval Architects and Marine Engineers with Vice-Admiral Edward L. Cochrane, Maritime Administrator, to head its 1952 Special Research Steering Committee.

▸ **Bruce Del Mar** (A.F.), who formerly headed the Special Projects Engineering Group at Douglas Aircraft Company, Inc., has organized a new company, Del Mar Engineering Laboratories, to undertake development work on aeronautical projects. The company's offices are at 3931 W. Slauson Ave., Los Angeles.

▸ **John A. Drake** (M.), Chief Engineer, Marquardt Aircraft Company, has been appointed to the N.A.C.A. Technical Subcommittee on Internal Flow.

▸ **Stanle J. Dzik** (A.M.), Globe Steel Tubes Company, was elected a member of the Promotion Committee for the second annual Air Pageant of the state of Wisconsin, which will be held September 6–7, 1952, at Milwaukee.

▸ **Dr. Hans W. Liepmann** (A.F.), Professor of Aeronautics, California Institute of Technology, was reappointed to the N.A.C.A. Subcommittee on Fluid Mechanics.

▸ **Dr. Frank E. Marble** (M.), Assistant Professor of Jet Propulsion and Mechanical Engineering, California

Institute of Technology, has been appointed to the N.A.C.A. Subcommittee on Combustion.

▸ **Charles Marcus** (A.M.), Vice-President, Bendix Aviation Corporation, will head the Aircraft Manufacturers Division of the 1952 Cancer Crusade. This is Mr. Marcus' fourth successive year as a volunteer leader.

▸ **Dr. Clark B. Millikan** (H.F.), Professor of Aeronautics and Director of the Guggenheim Aeronautical Laboratory, California Institute of Technology, was reappointed to serve on the N.A.C.A. Committee on Aerodynamics and as Chairman of the Subcommittee on Fluid Mechanics.

▸ **Dr. Glenn Murphy** (M.), of Iowa State College, has been named Head of the Department of Aeronautical Engineering, succeeding Carl N. Sanford (M.) (*q.v.*). Dr. Murphy, who has been serving as Professor of Theoretical and Applied Mechanics, will retain some of his responsibilities in that field. He will also continue as Senior Engineer in the Institute for Atomic Research.

▸ **Carl N. Sanford** (M.), of Iowa State College, has requested that he be relieved of his duties as Head of the Department of Aeronautical Engineering and be allowed to pursue his interests in teaching and research. Accordingly, he has returned to these duties as a Professor in the department.

▸ **Dr. E. E. Sechler** (A.F.), Professor of Aeronautics, California Institute of Technology, was reappointed to the N.A.C.A. Subcommittee on Aircraft Structures.

▸ **M. B. (Yank) Spaulding, Jr.** (M.), formerly Assistant Director of the Engineering Division, Air Transport Association of America, has opened offices in Room 800, 726 Jackson Pl., N.W., Washington, D.C. Mr. Spaulding is now doing technical representation before the federal agencies of the Government and particularly before the C.A.A., C.A.B., N.P.A., and D.P.A.

▸ **Don L. Walter** (T.M.), Manager, Engineering and Manufacturing, Marquardt Aircraft Company, has been appointed to the N.A.C.A. Technical Subcommittee on Engine Performance and Operation.

Members on the Move

The purpose of this section is to provide information concerning the latest affiliations of I.A.S. members. All members are, therefore, urged to notify the News Editor of changes as soon as they occur.

James Owen Anderson (T.M.), Engineering Draftsman "A," Tulsa Division, Douglas Aircraft Company, Inc. Formerly, Engineering Draftsman "B," Tulsa Division, Douglas.

William J. Arnold (T.M.), Tool Designer, MacRay Engineering Company. Formerly, Design Draftsman, Wean Equipment Corporation.

O. Garland Barnes, Jr. (T.M.), now Aeronautical Engineer, Chance Vought Aircraft Division, United Aircraft Corporation.

Major Julius L. Boggs, U.S.M.C.R. (T.M.), MABS-13, MAB-13, Navy 990, c/o Fleet Post Office, San Francisco. Formerly, Engineer "A," Testing Division, Power Plant and Mechanical Design Group, Douglas Aircraft Company, Inc.

Group Captain R. Harris Bray, R.C.A.F. (T.M.), Senior Technical Staff Officer, R.C.A.F. Station, St. Hubert, Que., Canada. Formerly, Director of Development, R.C.A.F., Ottawa, Ont.

John C. Brook (T.M.), Junior Engineer—Stress Analysis, Aircraft Division, Kaiser Metal Products, Inc. Formerly, Junior Engineer, Boeing Aircraft Company.

Jack V. Casamassa (A.M.), Sales Engineer, Russell and Company. Formerly, Engine Department Head, Academy of Aeronautics, Inc.

E. J. Catchpole (T.M.), Structural Analyst, Vickers-Armstrongs, Ltd., England. Formerly, Graduate Trainee, Vickers-Armstrongs.

Dr. Seville Chapman (M.), Head, Physics Department, Cornell Aeronautical Laboratory, Inc. Formerly, Acting Head, Physics Department, C.A.L.

Gene W. Clark (M.), Sales and Service Engineer, Associated Air Services. Formerly, Maintenance Engineer, Braniff Airways, Inc.

Otis J. Cofiniotis (M.), Design Engineer, Northrop Aircraft, Inc. Formerly, Design Engineer, Lockheed Aircraft Corporation.

Billy J. Cook (T.M.), Engineer "B" Design, Hayes Aircraft Corporation. Formerly, Designer, Design Operations Section, Chance Vought Aircraft Division, United Aircraft Corporation.

Philip E. Culbertson (T.M.), Aerodynamics Engineer, Consolidated Vultee Aircraft Corporation. Formerly, Research Associate, University of Michigan.

Daniel C. Curtin (T.M.), Engineering Draftsman "B," North American Aviation, Inc. Formerly, Engineering Draftsman, Ralph H. Decker, Inc., Consolidated Electrical Engineers.

Norbert J. Dabrowski (T.M.), Project Engineer, Research Department, Electric Boat Company. Formerly, Graduate Student, Columbia University.

Edward R. Dye (M.), Head, Industrial Division, Cornell Aeronautical Laboratory, Inc. Formerly, Head, Development Division, C.A.L.

Stanle J. Dzik (A.M.), Senior Special Machine and Product Designer, Engineering Department, Globe Steel Tubes Company. Formerly, Owner, Aircraft Design Company.

David Eisenberg (T.M.), Engineering Designer, Research and Development Laboratories, Hughes Aircraft Company. Formerly, Engineering Draftsman "A," Research and Development, Hughes.

Dr. Mark Foster (M.), Head, Development Division, Cornell Aeronautical Laboratory, Inc. Formerly, Department Head, Special Projects, C.A.L.

W. T. Fraser (T.M.), now Development Engineer, Allied Processes.

Wendell P. Garton (T.M.), Flight Test Engineer "B," North American Aviation, Inc. Formerly, on Extended Active Duty as Captain, U.S.M.C.R., S.M.S.-24, M.A.G.-24, M.C.A.S., Cherry Point, N.C.

G. Gonzalez Gomez (A.M.), Aeronautical Engineer, Engineering Office, San Carlos University, Guatemala City, Guatemala, C.A. Formerly, Assistant Engineer, Airport Section, Department of Public Works, Guatemala City.

Richard Hittner (T.M.), now Project Designer, Aeroflex Research, Inc.

Eugene B. Jackson (A.M.), Chief, Division of Research Information, N.A.C.A., Washington, D.C. Formerly, Chief, Office of Aeronautical Intelligence, N.A.C.A., Washington, D.C.

V. M. Kibardin (A.F.), Flight Test Branch, W-303, Civil Aeronautics Administration, Washington, D.C. Formerly, Physicist, Missiles Dynamics Section, National Bureau of Standards.

Alvin A. Lawrence (T.M.), Stress Analyst "C," Columbus Division, North American Aviation, Inc. Formerly,

(*Continued on page 92*)

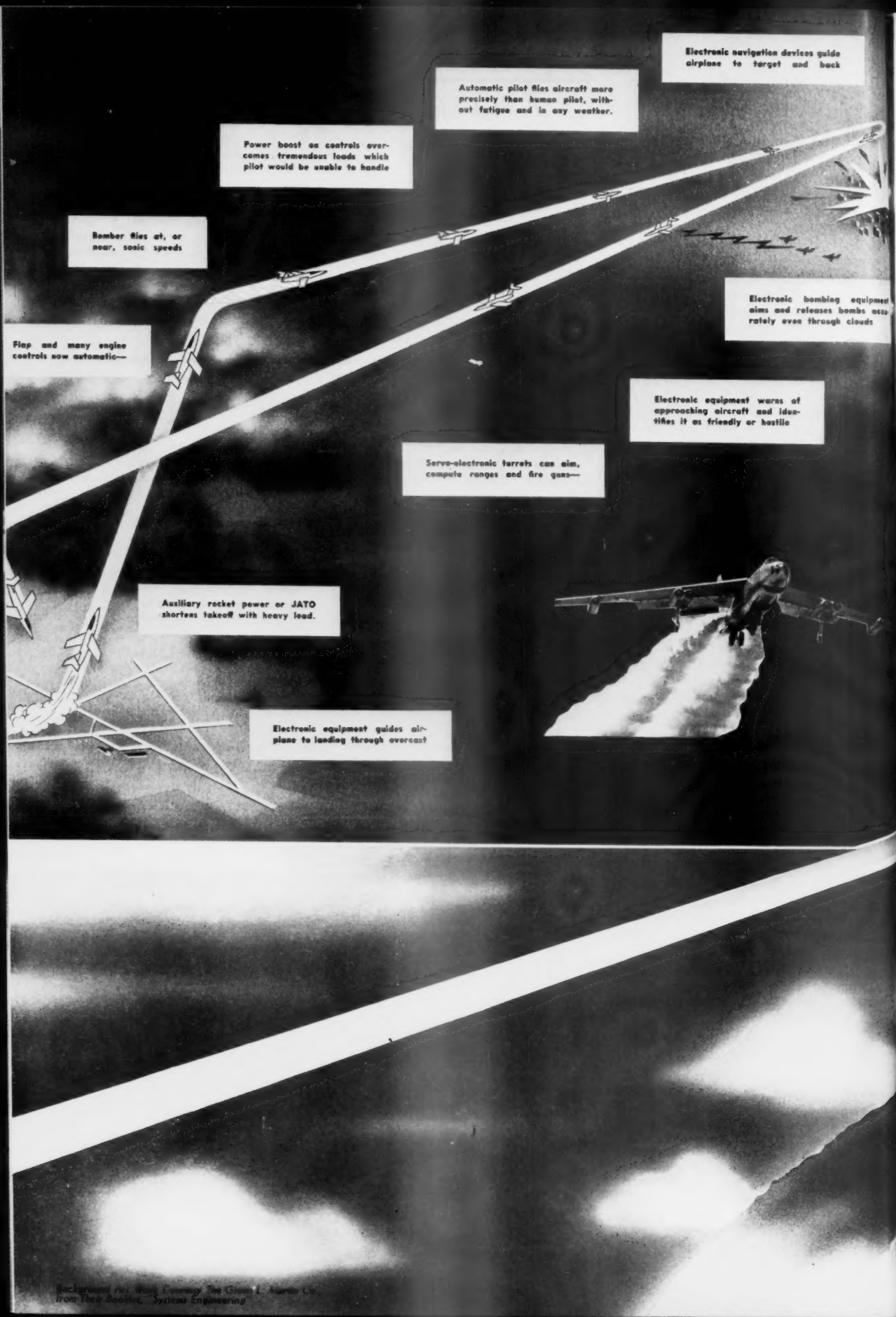
Necrology

Leland H. Lord

Leland Hume Lord, T.M.I.A.S., was killed on March 3 in the crash during a spin test of Fletcher Aviation Corporation's experimental FD-25A primary trainer.

Mr. Lord, who was employed by Fletcher Aviation Corporation as an aerodynamicist, was born in Charlottesville, Va., on November 3, 1918. He attended secondary school in Woodberry Forest, Va., and in September, 1937, entered Washington and Lee University as a freshman. The following September, he transferred to Parks Air College and was graduated from there in December, 1940, with a B.S. degree in Aeronautical Engineering.

He joined Vega Aircraft Corporation in January, 1941, as a Junior Draftsman and was later promoted to Design Engineer. Before he joined the staff of Fletcher Aviation Corporation, he served for a number of years with Radioplane Company as an aerodynamicist.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Power boost on controls overcomes tremendous loads which pilot would be unable to handle
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Electronic bombing equipment aims and releases bombs accurately even through clouds
Flap and many engine controls now automatic—
Electronic equipment warns of approaching aircraft and identifies it as friendly or hostile
Servo-electronic turrets can aim, compute ranges and fire guns—
Auxiliary rocket power or JATO shortens takeoff with heavy load.
Electronic equipment guides airplane to landing through overcast

Background for Wing Coverage, The Glenn L. Martin Co.
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Editorial

The Tail That Wags the Dog

Electronics—those gadgets we tucked away in the baggage compartment or stuck in that blank space on the instrument panel a few years ago—have all but taken over the airplane today. The vacuum tube not only has replaced the "seat of the pants," it now provides the eyes, ears, and physical prowess that lie beyond the capabilities of the human pilot.

The adaptation of electronics to aircraft and missiles has advanced the science of aeronautics immeasurably in recent years. What the future holds is anybody's guess. But it seems reasonable to assume that the air frame, together with its power plant, will always be the basic vehicle. Electronics can serve only to improve the performance, safety, and versatility of that vehicle, regardless of its aerodynamic configuration. Advancements in the development of either must naturally affect the other. The integration and control of both are, and should remain, primarily in the hands of the aeronautical engineering profession.

The aviation industry has been quick to recognize and take advantage of electronics. It has set up its own research departments, employed its own experts, and drawn from the general field of electronics those products and implements that have application to aeronautics. The electronics engineer has been pulled in to work side-by-side with the aerodynamicist, the stress analyst, and the aircraft designer. He has become an equally important member of a "systems engineering" team.

During this transition period, the Institute and the AERONAUTICAL ENGINEERING REVIEW have taken the initiative in fostering a closer relationship between the aeronautics and electronics professions. Through special meetings and published articles, we have attempted to present the problems peculiar to both and to coordinate the efforts toward the solution of those problems.

This special Electronics Issue of the REVIEW—the second annual edition of its kind—represents another concentrated effort in this direction. It is hoped that the articles, reviews, and advertising pages presented continuously through this magazine will assist in advancing the progress of electronics in aviation—helping to keep the "tail" and the "body" wagging in the same direction at the same time.

W. A. S.

Automatic Flight Control

CAPT. JAMES L. ANAST, USAF*
Wright Air Development Center

IN THE 38 YEARS since Lawrence Sperry demonstrated his "stable aeroplane" we have seen tremendous strides in automatic control development for aircraft. His equipment consisted of three gyroscopes that were connected to the control system in such a way that when the roll and pitch attitudes changed away from level, the system tended to restore the aircraft to its proper attitude.

This much control evidently sufficed for it to be called the "stable aeroplane." Now, as we take a look at the automatic controls that have been and are being developed for today's aircraft, we can see and appreciate the immensity of the requirements that must be fulfilled before we can label it a stable airplane.

Let us regard for a moment the transitions in control requirements which have taken place in the last few years. First of all, in World War II automatic pilots were used largely for relief on long flights, and, when the first critical situation came up, such as enemy attack or take-off and landing operations, the automatic pilot usually was turned off. It is now long past the time when pilot relief was the goal. We are now developing automatic control equipment that is necessary in order to accomplish the aircraft's mission.

The characteristics of modern warfare, the desirability for operation during all climatic and environmental conditions, and the characteristics of the aircraft themselves require controls that are demonstrably not achievable by primary human control.

I remember, and I believe that it is still prevalent today, standing instructions to turn off the automatic pilot when a thunderstorm is encountered. It might be interesting to note that for some time now research has been going on concerning the optimum manner in which automatic controls can alleviate the effect of heavy gusts on aircraft.

I believe the largest single factor, however, that necessitates automatic control is the characteristic of aircraft that tends to make stability and control incompatible.

Presented at the session on Electronics—II, Twentieth Annual Meeting, I.A.S., New York, January 28-31, February 1, 1952.

* Technical Assistant to Chief, All Weather Section, Flight Test Division.

There are no aircraft that are attitude stable. Disturbances can cause the aircraft attitude to diverge, persist indefinitely, or initiate undamped oscillations. A pilot can cope with this divergence but only with great effort and vigilance. An aircraft in flight may be described as a velocity vector. The success with which this vector resists change in direction describes its stability, and the success with which its direction can be changed describes its control capabilities.

In designing aircraft, a compromise is reached between stability and control ease, usually heavily weighted in favor of control. Often less attention is given in design to stability than to control, because skilled piloting may compensate for deficiencies in stability.[1]

It has been shown that a human pilot cannot tell the difference between 30 per cent damping and critical damping in the yaw axis. As a comparison, the damping coefficient for linear mechanical dynamic systems is 70 per cent for optimum response.[2] Thirty per cent damping represents a condition where several cycles of oscillation occur before a disturbance is quelled. Modern precision fire and bombardment systems practically dictate the use of stability augmentation regardless of the method because of the accuracy required. Actually, unless automatic equipment for some of our modern weapon systems were available, it would not be possible to utilize them as required.

Increased attitude stability has become necessary in other phases of flight traffic control maneuvers for groups of aircraft and, of course, approach and landing operations. All-weather operation in general, where attention must be given by flight crews to accurate navigation and other aspects of the mission, increases the requirement for additional stability. Being naturally unstable, the problem of carrying out a mission under instrument flying conditions with highly specialized aircraft becomes extremely difficult for even the most experienced pilot. Let us examine, then, the steps that have been taken to give us a "stable aeroplane."

Development of Equipment

We now have an assortment of electronic automatic pilots whose basic principles are identical. Deviations

from level attitude are measured by displacement gyroscopes. These errors are amplified to a level sufficient to energize motors that operate the control surfaces so as to restore the aircraft to its original attitude. The speed with which this can be done, without oscillation, is generally the criterion by which an automatic pilot is judged. Let us leave to one side for the time such things as reliability and fail-safe characteristics. A fairly satisfactory situation as far as reliability and failing safe are concerned is attested to by the planned use of nearly 600 automatic pilots by the world's leading air lines in 1952.[3]

Most automatic pilots today use, in addition to gyroscope displacement information, either the rate of departure or a "rate" gyroscope to give a better response to disturbances and to stabilize the control system. With the modern electronic automatic pilots, we have available, at least for our conventional aircraft, a device that provides a nondivergent, if not completely stable, aircraft. There is usually furnished a "pedestal" control of one kind or another in order that maneuvers can be made.

Here, then, we have the elements for attitude stability and maneuvering control. Whether or not this is a satisfactory arrangement, I would like to discuss a little later.

In addition to attitude stability and maneuvering control, it has become mandatory in some cases (particularly for some military uses), and desirable in others, to provide track control. This has become necessary because the automatic-pilot-equipped aircraft is only stable with respect to the air mass, and its flight path, therefore, is subject to any nonsymmetrical winds that prevail. In order to provide better navigation for the pilot, automatic couplers have been developed. This includes coupling, for example, to I.L.S, G.C.A., V.O.R., and other special auto tracking devices that have been developed for military purposes. They all have one purpose, however: to control the flight path of an aircraft according to navigation information supplied usually simultaneously to the automatic pilot as voltages and to the human pilot visually.

Our high-speed aircraft have accentuated a problem that has not been too important heretofore. It is the problem of adjustment of the constants in the control system. A compromise can be reached for the adjustments on automatic pilots for conventional aircraft that operate at medium altitudes and at medium air speeds. However, the advent of the jet aircraft with speeds past the sonic barrier and at very high altitudes requires a great range of adjustment of the constants of the control equipment. As a matter of fact, adjustment for optimum performance at approach speeds for most jet aircraft can result in entirely unsatisfactory and dangerous situations at cruising speeds. The great range of air density and dynamic pressure varies the response characteristics of the aircraft and its control effectiveness to a point where it is necessary to have automatic adjustment of the gain settings as a function of static and dynamic pressure. In some cases, the change from full fuel tanks to empty tanks deteriorates the performance of the control equipment.

This situation is further aggravated by the use of power boost systems in some jet aircraft which have not been designed to work with automatic pilot servo equipment, so that, when a servo is placed in a closed loop with a nonlinear power boost, the adjustment of the compensating elements of the automatic pilot is so critical that a prohibitively narrow range of external conditions can be tolerated. Thus, it appears that automatic "parametric controls," as they are called, are an essential element in the present-day development of automatic aircraft control equipment.

There have been many other improvements and techniques developed to improve automatic pilot performance. Some of these are: (1) integral control in attitude and track (or error corrector as known in some circles), (2) slaving of heading control to the earth's magnetic field, (3) automatic barometric altitude control, (4) data smoothers or signal filters, and (5) improvements in components such as servos, synchros, gyroscopes, etc.

As a result, it is possible to control conventional aircraft automatically in most phases of their flights in spite of weather. Exceptions to this are automatic landing and traffic control. There are reasons for this. In the case of automatic landing, the requirement is not yet too compelling. In the military, as well as for the civil air lines, the equipment in the rest of the control loop is not yet perfected to the point where it is feasible. In addition, there is a strong controversy as to the economic value of providing complete automatic landing. I believe both of these barriers will be removed eventually. Automatic traffic control is not yet available for another reason. In view of the larger tolerances, it may well be that manual control in the aircraft will suffice for the aircraft densities that will prevail in the future.

Performance

It may be interesting to examine the results of the Air Force experimentation in approach control which was carried out by the All Weather Flying Division (Fig. 1). This chart was made from statistical examination of the accuracies of different approach systems in the neighborhood of touch-down. The curves show percentages of runs that were within certain arbitrary distances from the glide path (from 0 to 200 ft). It can be seen that there are two families of curves: that representing manually controlled approaches and that representing automatically controlled approaches.

It should be explained that these tests were not run under any special conditions. They were made at Clinton County Air Force Base, Wilmington, Ohio, on a runway with the prevalent wind directly across the runway, which may explain in part why there is a larger scatter of errors than might normally be expected

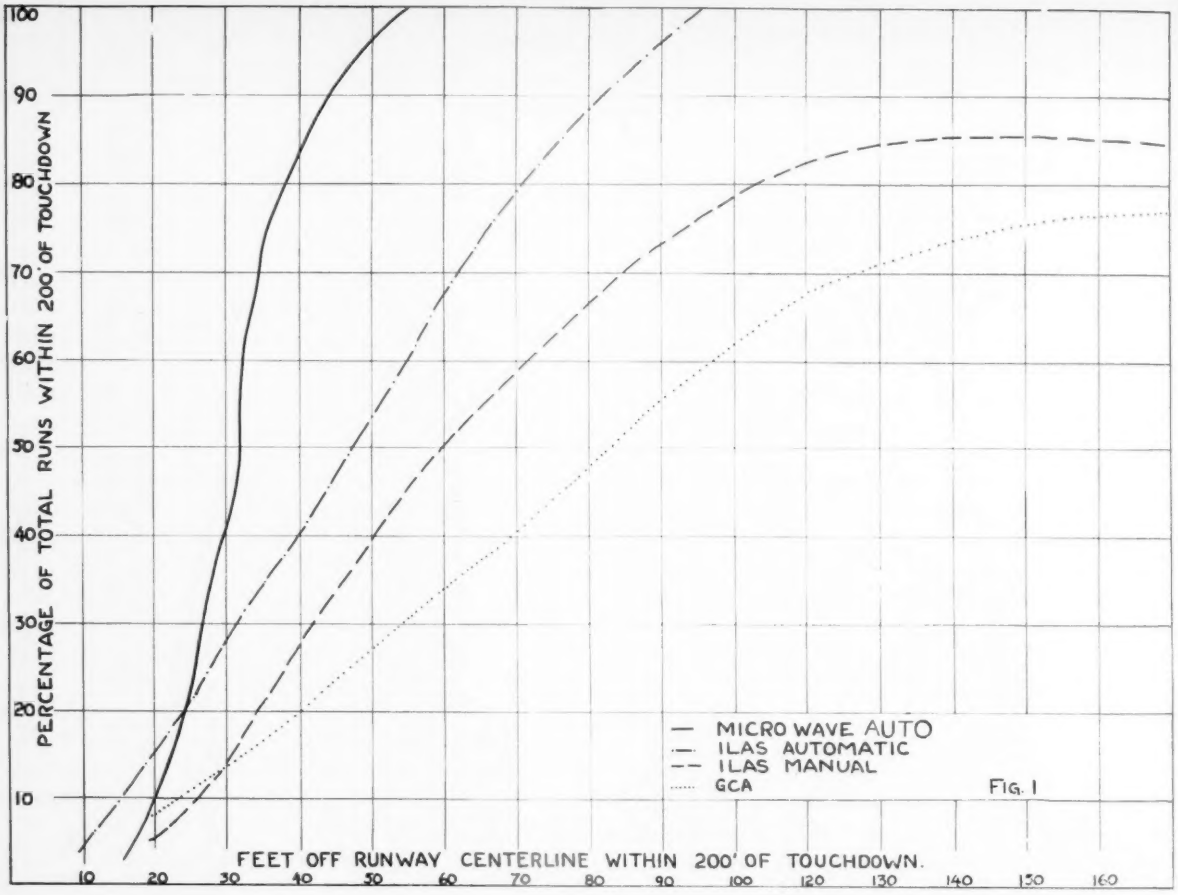

FIG. 1

with either manual or automatic approach. Ordinary maintenance was carried out, and, other than initial calibration of the air-borne equipment, no attempt was made to refine the control over and above that which might be expected in the field. As a result, we believe that this chart is a realistic indication of what may be expected when different approach systems are utilized. From these data and with consideration for aircraft control dynamics and the heading errors that exist concurrently with displacement errors, we have deduced in general that manual systems can be utilized with a 95 per cent expectation of success operating to limits of 200+ ft. and $^3/_4$ mile, and that automatic G.C.A. or I.L.S. would have a 95 per cent expectation of success when used down to visibility limits of 100 ft. and $^3/_8$ mile. It should be noted that the most precise system that we measured (the 2,600 mc. I.L.S.) allows operation down to 50 ft. and $^1/_8$ mile. This comes extremely close to zero-zero landing. But operation down to zero feet is not believed possible through refinement of present equipment. This will require new techniques to provide a higher track accuracy and new methods of landing control.

There are several schemes under development at the present time to provide complete automatic landing. They involve the use of absolute height measurement to provide an exponential series of tracks in the vertical and the use of new methods of directional track control. The first method utilizes a navigation reference of much higher precision than has been utilized before. The second attacks the problem from the air-borne point of view. It recognizes that the navigation reference has superimposed on it effectively random "noise" at such frequencies and magnitudes as to prevent accurate following with ordinary closed-loop operation. It assumes that this "noise" is symmetrical or, in other words, that the average value of the navigation signal is of high accuracy. As was mentioned above, present-day automatic pilots provide stability only with respect to the air mass, and one cannot expect to use low gain systems to prevent instability in track because of the wind gust disturbances that are highly detrimental, particularly for landing operations.

If we could maintain track stability over a small number of seconds, then the accuracy of our present navigation equipment would be sufficient to provide at least directional control for automatic landing. In order to provide stability with respect to the earth, we must use inertial or aerodynamic references. If the aircraft track is stabilized by using the disturbances themselves, or the affect of the disturbances, then we can correct any error that builds up in the inertial system by using the averaged signal from the navigation reference. There has been active research and

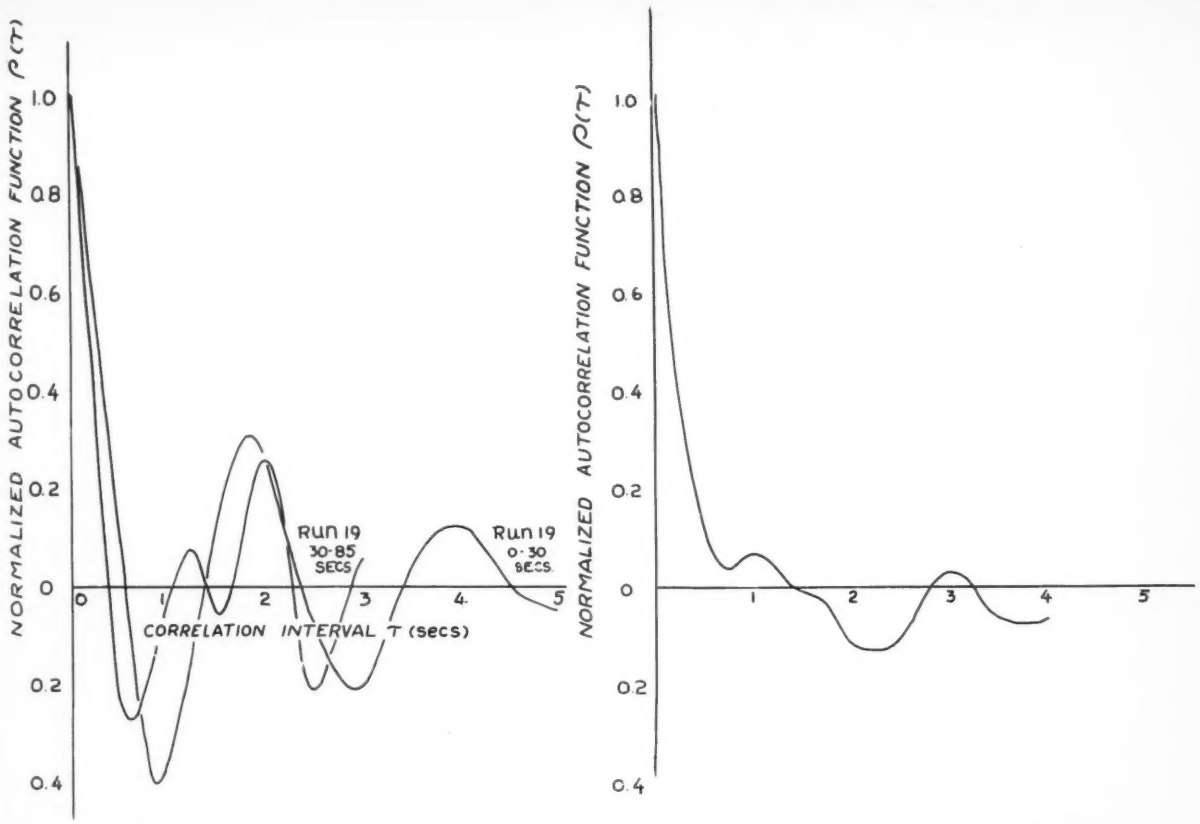

FIG. 2. Autocorrelation I.L.A.S. beam noise—Patterson localizer. (Curve on right is for Run 19, 0–85 sec.)

experimentation for over a year in an attempt to determine if this is a practical means for the solution of the tracking problem for automatic landing. (Actually, this technique can be likened to the use of the free gyroscope coupled to a flux value to give directional control and represents the use of a relatively noisefree but inaccurate reference combined with a noisy but accurate reference, which has the advantage of the desired quality in each reference.)

DESIGN PROBLEMS

In designing automatic aircraft control equipment, it has been unusual, when data were available on all the remaining components required, to work in the same control loop. For example, for approach control, the design of the automatic pilot should be made so as to compensate for characteristics of the reference data from the ground transmitter and the glide path which are distorted by anomalous reflections of the electromagnetic energy, the dynamic characteristics of the airborne reception equipment, the dynamic response of the aircraft to control movements, and its response to gusts, and lastly, gust characteristics. To aggravate the situation, development and even research on the different components are usually conducted by separate organizations that are responsible only for their particular component. It has indeed been a rarity to find an individual or group fully conversant with the dynamics of components other than its own. The tendency has been for navigation equipment engineers to consider the aircraft-automatic pilot combination as simple, single-order response systems and for automatic pilot engineers to treat navigation system vagaries as something merely to be filtered out. This has led to incompatibility in some cases which could have been prevented had the system been considered as a whole prior to design of the components. Recently, however, there has been a great impetus given throughout the country to system engineering that has already made its impact on development of equipment. Data on dynamics characteristics of aircraft are now becoming more available, and the concept of weapons system design is gaining support daily in the Air Force.

It has been extremely difficult in the Air Force to guide development of equipment for automatic approach and landing because of the lack of engineering data on the performance of the different systems. There has been a good deal of controversy about where the emphasis in development should be placed—in the air-borne or the ground equipment. As a result, gradual uncoordinated improvements have been made in all the components. They are mostly refinements, however, and in general are not supported by experimental system data. For example, we have developed a series of I.L.S. equipment at higher and higher frequencies based on the fact that beam bends will be increased

in frequency and decreased in magnitude. This, of course, is generally advantageous, but there has been no experimental verification of the actual required characteristics of electronic landing systems. Recently, the ANDB, in recognition of this problem, initiated a program with the USAF at the All-weather Flying Division which I shall outline for you.

The purpose of the program is to measure the operational performance of eight approach control systems with five representative aircraft, three different air-borne visual indicators, and four automatic pilots. In this program, an analysis is made of the total error and the composition of the error to determine the relation between the dynamic characteristics of the components in the system and their contribution to the system dynamic characteristics. From these data, through theoretical extrapolation and analog computer studies, it is anticipated that specifications will be derived for equipment to meet the desired operational requirements. These specifications will be given in terms of dynamic performance. A typical specification may well be that the "noise" spectrum of the guidance system as seen by the air-borne receiver must be within a certain envelope in the region of touch-down. The engineers concerned with development of guidance systems will then have available to them realistic performance characteristics toward which they can work.

This program is well under way now, and some results of "beam mapping" the standard USAF I.L.A.S. are available. It may be interesting to note that beam mapping, as such, was not possible. It turns out that the beam can be described much better as a spectrum of extraneous frequencies that the aircraft will encounter when being controlled. Even that can not generally be repeated but is a function of the position on the beam and position with respect to reflecting surfaces. So far, we do not have enough data reduced to correlate this accurately. Typical autocorrelation functions of the noise are shown in Fig. 2. It should be noted that, for frequencies down to approximately 2 cycles, the noise is fairly "white," and that, for the lower frequencies, which are generally attributable to space bends, the two samples show different distributions of frequencies. We hope to have additional data soon through expansion of our data reduction facilities which will enable us to describe the beam noise in a system.

In order to extrapolate accurately, All-Weather decided to set up an analog of the control system being tested. The aircraft dynamics is inserted on a one to one time basis with Goodyear analog computers. An analog or the actual equipment represents the automatic control equipment. Loading stands are used to simulate hinge moments, and the beam geometry, beam noise, and gusts are also inserted into the system. The simulator is used for two purposes—to determine initial calibration settings and to furnish an accurate model with which to replace the various components and carry out analyses of the different combinations of components and thus eliminate a large percentage of actual flight measurement.

We have had some success already on reproducing in our laboratory an approach system using the F-5 automatic pilot. However, a complete pilot experiment has not yet been accomplished, and, in spite of our enthusiasm for the combined use of flight measurement and analog simulation for approach control analysis, it is too early to report on the practicality of this technique.

Areas of Development

The All Weather Section, Flight Test Division, has for nearly 2 years been active in investigating the use of artificial stability in aircraft. As mentioned previously, the amount of stability obtained in modern high-speed aircraft is severely restricted by practical demands of the geometry affecting performance. Therefore, automatic means of creating stability is vitally necessary if the mission is to be performed. The All Weather Section investigation involves two facets of artificial stability.

First, the characteristic equations were examined for artificially stabilizing the modes of motion. An aircraft's motion can usually be described by a set of linear differential equations with nondimensional coefficients. These coefficients determine the aircraft's response to disturbances and the quality and amount of maneuvering that can be accomplished. Our study indicated that considerable improvement could be obtained in the lateral and longitudinal transient response and the longitudinal phugoid by changing the value of these coefficients through the use of automatic control. Second, consideration was given to the "feel" for the human pilot when the system was in use. It was decided that command should be exercised proportional to force applied to the pilot's control and thus preserve the force feedback enjoyed normally by the pilot. Whether the rate of change of the various attitudes should be a function of applied force or whether the attitude itself would be a function of force was the subject of a good deal of controversy. It was agreed that the type or phase of mission would dictate the optimum method of control and it was decided to investigate the various techniques. Subsequently, an E-4 automatic pilot was modified to receive signals from strain gages integral to the control column and rudder pedals of a B-17G. The "force wheel" system, as we called it, served to demonstrate the artificial stability technique, having successfully operated for a period of several months in 1951. In effect, the aircraft was stable and yet allowed better maneuverability than was available either manually or through the pedestal controller.

Since then, we have initiated a more comprehensive flight research program including an artificial stability study and instrumentation of a C-45 in conjunction with Cornell Aeronautical Laboratory, Inc. We hope to show the advantages of artificial stability, not only for attitude control but for flight-path control. Plans

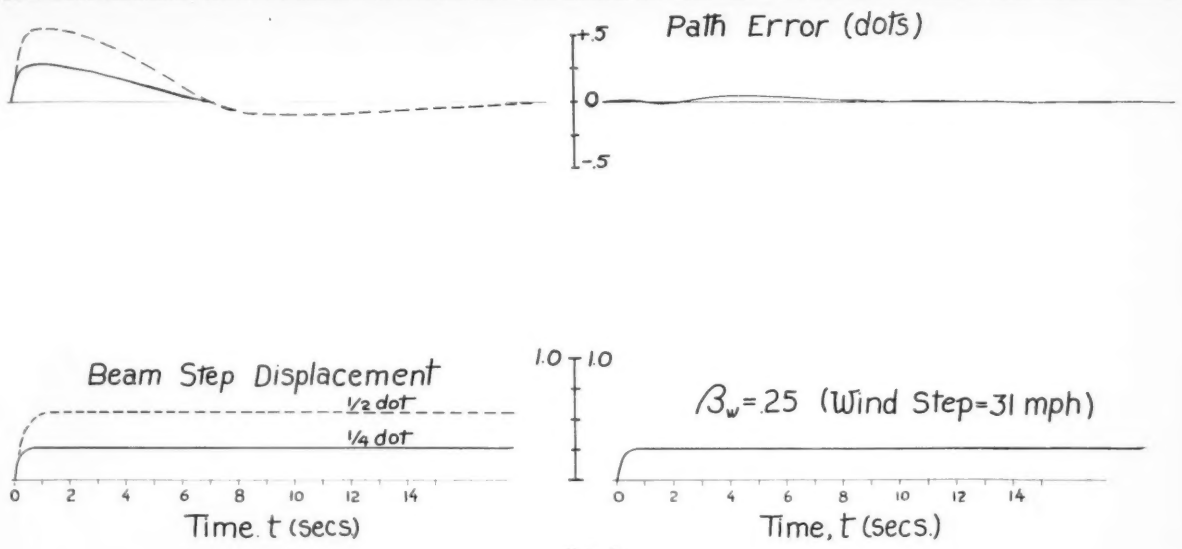

FIG. 3.

have been made to evaluate the use of artificial stability in flying approaches, interception, and traffic control. Due in part to this research, control systems utilizing the principle of simultaneous flight-path stability and control are now under consideration for several different weapons systems.

Another technique that is allied to the principles previously described is a more sophisticated approach to aircraft control. The principle is as follows: In changing the direction of flight in order to reduce a track error, the control surfaces are actuated by an open-loop command that, in effect, predicts the time history to reduce the initial error. In this manner, more rapid response can be attained to initial errors and a steady state can be reached earlier since trim changes can be programmed also. This is going on in automatic flare-out landing investigations among others.

I would like to mention briefly the work being carried out on combined boost and servo control. It is the intent of these programs being carried out with several manufacturers to design a power actuator that can serve equally well as a power boost or as a servo for automatic control equipment. This will, when reduced to practice, eliminate the difficulties arising from "mismatch" of automatic pilot servos and power boost equipment and permit use of artificial stability without weight penalty.

As happens often in the evaluation of control systems, a new technique was turned up at All Weather in analyzing approach control which promises to minimize the problem of aircraft instability with respect to a ground track. The classical method for approach control is to close the heading attitude loop as tightly as possible and superimpose command track error signals transformed to give the required track stability.

The rigidity in direction, brought about by closed-loop heading control, although it minimizes the error in heading, is at the complete mercy of translation due to changing side forces. As a consequence, a correction is not applied until sufficient track error signal is built up to pass the lower threshold of the track control loop. This is detrimental because the characteristic time of track control on approach is extremely long (varying between 10 and 30 sec.). A low characteristic time is sought in order to compensate as rapidly as possible for wind forces. In order to do this, the track loop gain (bank angle/degree of beam) is increased as high as possible consistent with the stability obtainable in the face of beam noise. Filtering of the error signal to minimize the effect of beam noise requires that a lower outside loop gain be used if stability is to be achieved, so that a compromise must be reached between stability and rapidity of control.

If there were no wind or if the aircraft were impervious to wind gusts, the signal could be filtered considerably, the gain backed off, and the characteristic time increased accordingly. The aircraft could then "coast" through the beam bends and stabilize on the average of the beam and undoubtedly effect accurate landings on every attempt. Unfortunately, the aircraft does not "coast" through the beam because it is susceptible to wind forces, and we are faced with a compromise between high response to gusts and low response to beam noise. This compromise, of course, affects the accuracy of track control, and, as a result, the scatter on a standard I.L.S. can be expected to be plus or minus nearly 100 ft.

Lieutenant F. D. Graham, in his simulator studies at All Weather, discovered that simultaneous reduction of wind effect can be obtained with a reduction in beam noise effect. This is done by opening the feedback loop in yaw and allowing the aircraft to weathercock into the prevailing wind as determined by the angle of sideslip. The B-25 aircraft was chosen because it has a relatively high directional stability, so that no additional stability need be added in order to accomplish fairly stable weathercocking. Then, a 1-sec.

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Airport Taxi Radar

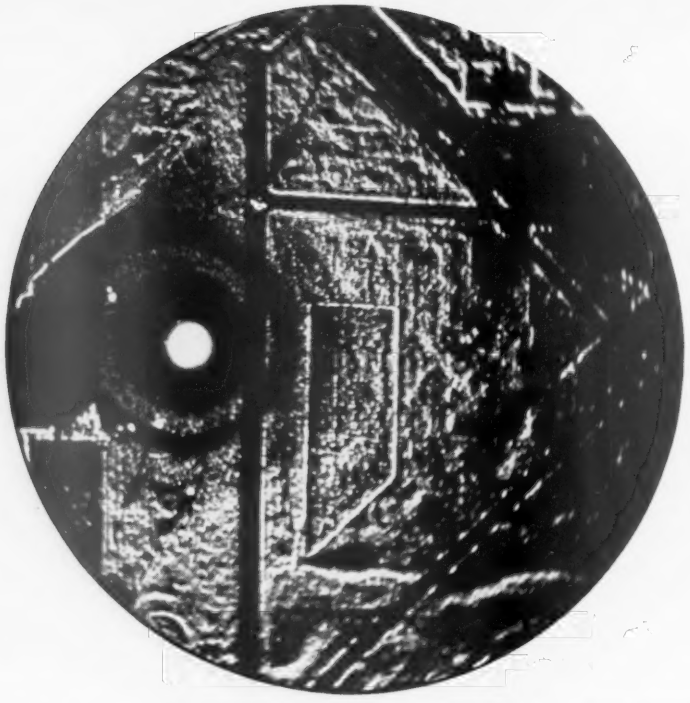


FIG. 1. View on radar scope of Weir Cook Municipal Airport, showing aircraft at intersection of runways. White spot marks location of detection equipment.

RADAR, SURROUNDING ONLY the airport surface, is being developed to supplement and extend the range of vision of airport traffic controllers. The control of ground traffic has become increasingly difficult. Modern congested air terminals with 2-mile runways and a variety of ground traffic is hard to observe from the control tower, especially at night or under restricted visibility. Traffic controllers are therefore watching with keen interest the development of "Taxi Radar."

The opportunity for fully monitoring ground traffic conditions has been much advanced through Taxi Radar (Airport Surface Detection Equipment), which is now being subjected to tests and observation under operating conditions.

The results of the evaluation to date indicate that Taxi Radar can perform a valuable function in providing traffic controllers with information necessary to clear aircraft for take-off and landing operations on live runways during certain conditions of poor visibility. It can also help to guide aircraft to runway turn-off points and do a fairly good job of turning aircraft onto taxiways at slow speeds.

The possibility of this type of apparatus serving as an aid to controllers in the not too distant future thus appears assured. Some authorities estimate that commercial installations will be feasible within 4 to 6 years. Fig. 1 indicates that considerable progress has already been made to provide Tower Controllers with visual aids that will increase efficiency in handling ground traffic at busy airports and greatly increase safety for all airport users. Observers working with the equipment have indicated that, in most instances, photographs do not do justice to the scope presentation as compared to observation with the human eye. The photograph shown is of a display tube (PPI) during one revolution of the antenna, showing the airport runways with an aircraft at a runway intersection.

The development and application of surveillance type radar for this purpose has been sponsored by the Air Navigation Development Board with the object of producing a common system for civil and military airport traffic control. This research program has been supervised by the Rome Air Development Center, Rome, N.Y. The evaluation program is supervised by the Civil Aeronautical Administration, Technical Division, Indianapolis, Ind. Refinement and development of the apparatus was handled under a contract with Airborne Instruments Laboratory, Mineola, N.Y., working with a first-test-model constructed by Gilfillan Brothers, Los Angeles, Calif.

Those engaged in the technological research and development of this type of equipment strongly indicate that considerable work remains to be done before they will concede it is ready for full usefulness as a ground traffic control instrument. There is, however, agreement that Taxi Radar can greatly reduce the hazard and delay experienced during periods of heavy traffic and bad weather by producing a continuous view of all runways, taxi strips, and parking areas. Performance of experimental models indicates that problems of the controller in visualizing runways beyond his normal area of vision will be reduced.

Fig. 1 gives evidence that easily identifiable outlines of moving vehicles, buildings, and other stationary obstructions are provided with sufficient definition to establish their location. The path of moving objects can be easily determined because their progress can

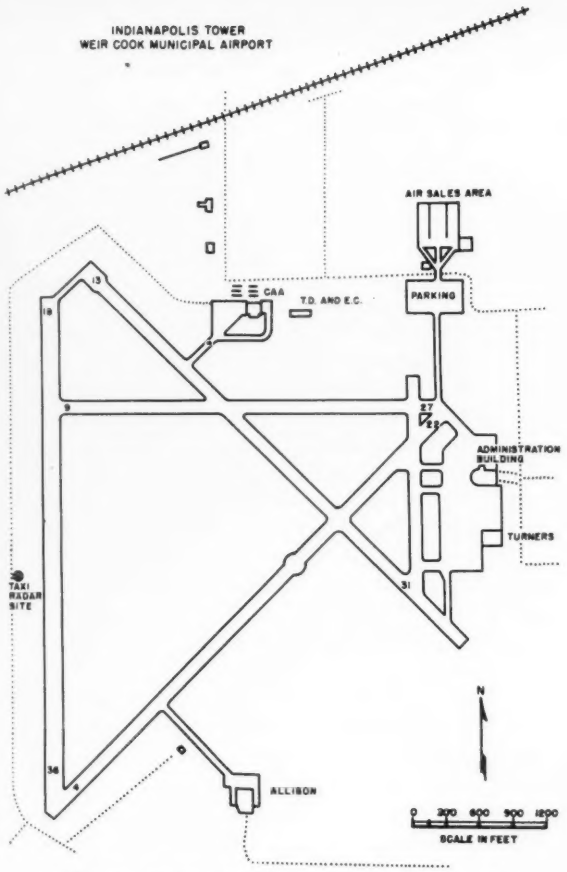


FIG. 2. Sketch of Weir Cook Municipal Airport, Indianapolis, Ind.

actually be followed by observation of the scope. With close scrutiny of the unretouched photo, we find additional information is available indicating changes and hazards that may occur in the typography of the ground area. An example of this is illustrated by the clearly defined trapezoid outline in the center of the field. The white outline is a furrow made by a common farm-type plow.

Test performances under extreme weather conditions have produced comparable observation of snow fences or similar changes that may occur on the field area. Plans now being formulated for further development in Taxi Radar will include an engineering model of the equipment along with work attempting to overcome degradation that may occur during heavy rains and provide radio link facilities that will permit optimum setting of the radar on the airport with the displays at desired controller locations. As now planned, information gathered by the radar must be displayed in a manner that will present to the controller a picture of the airport (renewed approximately once each second) which is accurate and yet not too confusing or detailed.

A radar set is capable of economical operation, continuous presentation, and excellent discrimination; the system is flexible, permitting information obtained to be displayed in various manners; and it can be installed or removed with ease. It appears that a radar installation may be cheaper than any other method and may eventually be capable of furnishing completely automatic operation, giving the pilot full information without additional operations of the controller other than monitoring. Thus, Taxi Radar appears to be a desirable adjunct to any navigation system used to assure all-weather airport traffic capacity. With the progress now being made in development of radar and other electronic aids to navigation, it appears evident that many new devices and equipments will be available to aid controllers in reducing hazards of increased air traffic.

FIG. 3. Airport Surface Detection Equipment—ground installation.

Present Status of *Transistor Development**

J. B. MORTON†
Bell Telephone Laboratories

(1) Introduction

When the transistor was announced about 4 years ago, it was felt that a new departure in communication techniques had come into view. Here was a mechanically simple device that could perform many of the amplification functions over which the electron tube had long held a near monopoly. The device was small, required no heater power, and was potentially rugged; moreover, it consisted of materials that might be expected to last indefinitely long, and it did not appear to be too complicated to make.

However, as might be expected for a newly invented electron device, the practical realization of these promises still required the overcoming of a number of obstacles. While the operation of the first devices was well understood in a general way, several items were limiting and puzzling, for example:

(a) Units intended to be alike varied considerably from each other—*the reproducibility was bad.*

(b) In an uncomfortably large fraction of the exploratory devices, the properties changed suddenly and inexplicably with time and temperature, whereas other units exhibited extremely stable characteristics with regard to time—*the reliability was poor.*

(c) It was difficult to use the theory and then existing undeveloped technology to develop and design devices to a varied range of electrical characteristics needed for different circuit functions. Performance characteristics were limited with respect to gain, noise figure, frequency range, and power—*the designability was poor.*

Before the transistor could be regarded as a practical circuit element, it was necessary to find out the causes of these limitations to understand the theory and develop the technology further in order to produce and control more desirable characteristics.

Over the past 2 years measurable progress has been made in reducing, *but not eliminating*, the three listed limitations.

These advances have been obtained through an improved understanding, improved processes, and, very importantly, through improved germanium materials. As a result:

(a) The beginnings of the method have evolved in the use of the theory to explain and predict the electrical network characteristics of transistors in terms of physical structure and material properties.

(b) It is now possible to evaluate some of the effects and physical meaning of empirically derived processes and thereby to devise better methods subject to control. Previously, inhomogeneities in the material properties masked the dependence of the transistor electrical properties even on bulk properties (such as resistivity) as well as on processing effects.

(c) As a result, on an exploratory development level, it is now possible to make transistors in the laboratory to several sets of prescribed characteristics with usable tolerances and satisfactory yields.

(d) Such transistors are greatly improved over the old ones insofar as life and ruggedness are concerned, and some reduction in temperature dependence has been achieved. However, it is not to be inferred that all reliability problems are solved.

(e) It has become possible in the laboratory to explore experimentally some of the consequences of the theory with the result that point-contact devices with new ranges of performance are indicated. Even more importantly, new *p-n* junction devices have been built in the laboratory, and these junction devices have indicated an extension in several of the performance characteristics.

(f) By having interchangeable and reliable devices with a wider range of characteristics, it has become

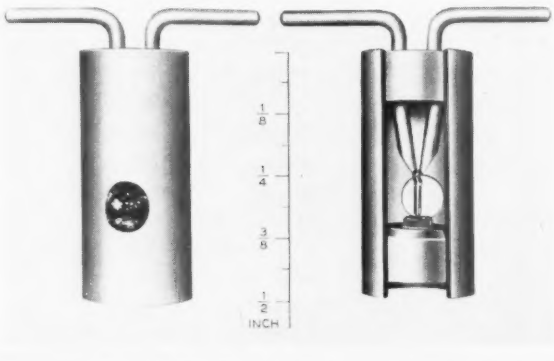


Fig. 1. The Type A transistor structure.

* Copyright 1952, American Telephone and Telegraph Company. Presented at I.A.S. Twentieth Annual Meeting by A. E. Anderson, Member of Technical Staff, Bell Telephone Laboratories, this paper is also appearing in the May issue of *The Bell System Technical Journal.*

† Electronics Apparatus Development Engineer.

possible to carry on exploratory circuit and system applications on a more realistic basis. Such applications effort is, in turn, stimulating the development of new devices toward new characteristics needed by these circuit and system studies.

It is the purpose of the remainder of this paper to give an overall but brief summary of recent progress made at Bell Telephone Laboratories in reducing the above-mentioned limitations on reproducibility, reliability, and performance. Since a fair number of types of devices is currently under development, each with different characteristics to be optimized, the data will be presented as a sort of montage of characteristics of several different types of devices. It is not to be inferred that any one type of transistor combines all of the virtues any more than such a situation exists in the electron tube art. Moreover, it will be impossible in a paper of practical length to present complete detailed characteristics on all or even several of these devices under development; nor would it be appropriate, since most of these data are on devices currently under development. Rather, what is desired is a summary of progress across the board to give the reader an integrated and up-to-date picture of the current state of transistor electronics.

(2) Reproducibility Status

(2.1) *Description of Transistors*

Before quantitative data comparing the characteristics of past with present transistors are presented, it will be useful to review briefly physical descriptions of the various types of transistors to be discussed. Fig. 1 shows a cutaway view of the now familiar point-contact cartridge-type transistor. All of the early transistors were of this general construction, and the characteristics of a particular one, called the Type A,[1] will be used as a reference against which to measure results now obtainable with new types under current development. Fig. 2 is a semischematic picture of the physical operation of such a device. Pressing down upon the surface of a small die of *n*-type germanium are two rectifying metal electrodes, one labeled *E* for emitter, the other *C* for collector. A third electrode, the base, is a large-area ohmic contact to the underside of the die of germanium. The emitter and collector electrodes obtain their rectifying properties as a result of the *p-n* barrier (indicated by the dotted lines) existing at the interface between the *n*-type bulk material and small *p*-type inserts under each point. When the collector is biased with a moderately large negative voltage, in the reverse direction, so that the collector barrier has relatively high impedance, a small amount of reverse current flows from the collector to the base in the form of electrons as indicated by the small black circles. Now, if the emitter is biased a few tenths of a volt positively in the forward direction, a current of holes (indicated by the small open circles) is injected from the emitter region into the *n*-type material.

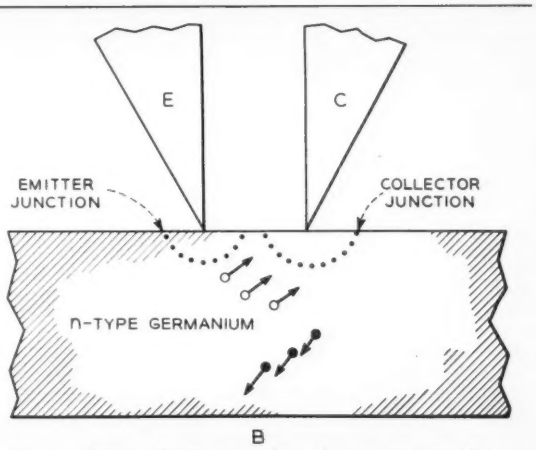


Fig. 2. Schematic diagram of a point-contact transistor.

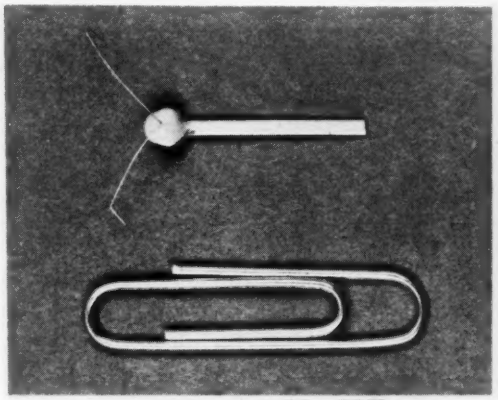


Fig. 3. Point-contact transistor.

These holes are swept along to the collector under the influence of the field initially set up by the original collector electron current, thus adding a controlled increment of collector current. Because of their positive charge, these holes can lower the potential barrier to electron flow from collector to base and thus allow several electrons to flow in the collector circuit for every hole entering the collector barrier region. This ratio of collector current change to emitter current change for fixed collector voltage is called alpha, the current gain. In point-contact transistors, alpha may be larger than unity. Since the collector current flows through a high impedance when the emitter current is injected through a low impedance, voltage amplification is obtained as well.

Some of the new transistors are point-contact transistors similar in physical appearance to the Type A. However, their electrical characteristics will be shown to be significantly improved over the old Type A not only insofar as reproducibility and reliability are concerned, but also as to range of performance.

For use in miniature packaged circuit functions, the point-contact transistor has been miniaturized to contain only its bare essentials. Fig. 3 is a photograph of a so-called "bead" transistor (compared to a paper

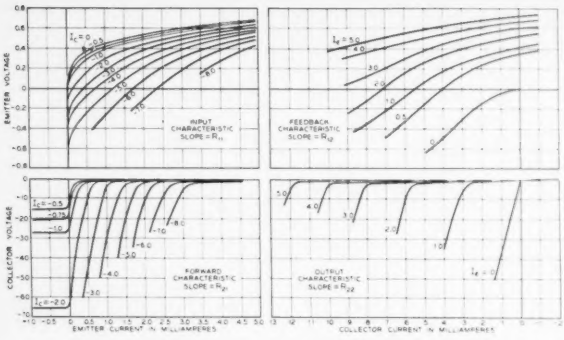

EMITTER VOLTAGE
INPUT CHARACTERISTIC SLOPE = R_{11}
FEEDBACK CHARACTERISTIC SLOPE = R_{12}
COLLECTOR VOLTAGE
FORWARD CHARACTERISTIC SLOPE = R_{21}
OUTPUT CHARACTERISTIC SLOPE = R_{22}
EMITTER CURRENT IN MILLIAMPERES
COLLECTOR CURRENT IN MILLIAMPERES

FIG. 4. M1689 static characteristics.

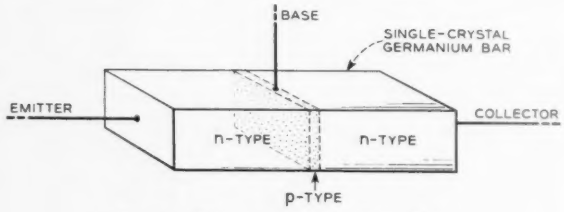


FIG. 5. The *n-p-n* junction transistor.

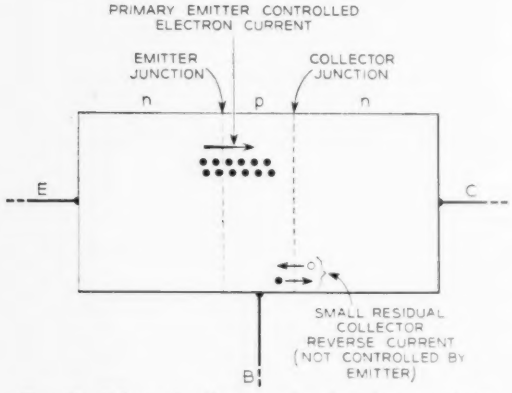


FIG. 6. Schematic diagram of a junction transistor.

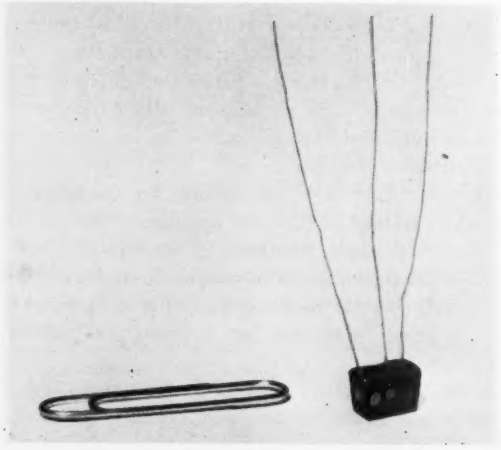


FIG 7. M1752 junction transistor.

clip for size). Several of the current development types are being made in this form.

In Fig. 4 is shown the family of static characteristics representative of the M1689 bead-type transistor. Note in particular the collector family that gives the dependence of collector voltage upon collector current with emitter current as parameter. These characteristics may be thought of as the dual to the plate family of a triode.[2] The slope of these curves is nearly the small-signal a.c. collector impedance of the transistor.* For a fixed collector voltage of −20 volts, when the emitter current is changed from 0 to 1 milliampere, note that the collector current correspondingly changes slightly more than 2 milliamperes, indicating a current gain, alpha, of slightly more than two.

Newest member of the transistor family recently described by Shockley, Sparks, Teal, Wallace, and Pietenpol is the *n-p-n* junction transistor.[3, 4] Fig. 5 is a schematic diagram of such a structure. In the center of a bar of single crystal *n*-type germanium there is formed a thin layer of *p*-type germanium as part of the same single crystal. Ohmic nonrectifying contacts are securely fastened to the three regions as shown, one being labeled emitter, one base, and one collector. In many simple respects, except for change in conductivity type from *p-n-p* in the point-contact (see Fig. 2) to *n-p-n* in the junction type, the essential behavior is similar.

As shown in Fig. 6, if the collector junction is biased in the reverse direction—i.e., electrode *C* biased positively with respect to electrode *B*—only a small residual back current of holes and electrons will diffuse across the collector barrier as indicated. However, unlike the point-contact device, this reverse current will be much smaller and relatively independent of the collector voltage because the reverse impedance of such bulk barriers is so many times higher than that of the barriers produced near the surface in point-contact transistors. Now again, if the emitter barrier is biased in the forward direction, a few tenths of a volt negative with respect to the base is adequate. Then a relatively large forward current of electrons will diffuse from the electron-rich *n*-type emitter body across the reduced emitter barrier into the base region. If the base region is adequately thin so that the injected electrons do not recombine in the *p*-type base region (either in bulk or on the surface), practically all of the injected emitter current can diffuse to the collector barrier; there they are swept through the collector barrier field and collected as an increment of controlled collector current. Hence, again, since the electrons were injected through the low forward impedance and collected through the extremely high reverse impedance of bulk type *p-n* barriers, very high voltage amplification will result. No

* As shown by Ryder and Kircher,[1] the a.c. collector impedance, $R_c = R_{22} - R_{12}$, where R_{22} is the open-circuit output impedance and R_{12} is the open-circuit feedback impedance. Usually $R_{22} \gg R_{12}$.

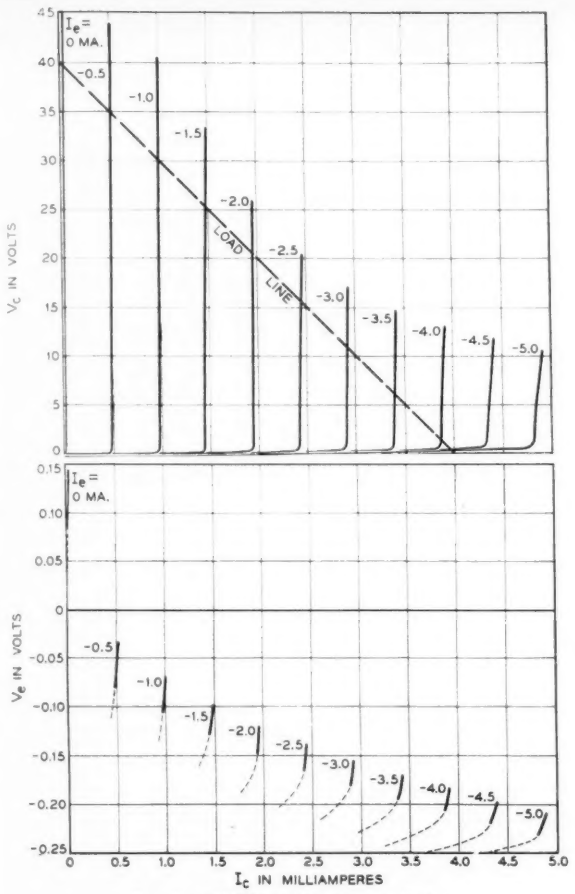


FIG. 8. M1752 static characteristics.

current gain is possible in such a simple bulk structure, and the maximum attainable value of alpha is unity. However, because the bulk barriers are so much better rectifiers than the point-surface barriers, the ratio of collector reverse impedance to emitter forward impedance is many times greater, more than enough to offset the point-contact higher alpha; thus, the junction unit may have much larger gain per stage.[1, 3, 4] Fig. 7 is a photograph of a developmental model of such a junction transistor called the M1752.

The upper part of Fig. 8 is a collector family of static characteristics for the M1752 *n-p-n* junction transistor. By way of comparison to those of the point-contact family, note the much higher reverse impedance of the collector barrier (relatively independent of collector voltage) and the correspondingly smaller collector currents when the emitter current is zero. In fact, Fig. 9 is an expanded plot of the lower left rectangle of the collector family of Fig. 8. The almost ideal straight-line character and regular spacing of these curves persist down to voltages as low as 0.1 volt and currents of a few microamperes. Thus, essentially linear Class A amplification is possible for as little collector power as a few microwatts. Constant collector power dissipation curves of 10, 50, and 100 microwatts are shown dotted for reference.

(2.2) *Reproducibility of Linear Characteristics*

In describing progress in the reproducibility of those transistor characteristics pertinent to small-signal linear applications, one possible method is to give the statistical averages and dispersions in the linear open-circuit impedances of the transistor as defined by Ryder and Kircher.[1] Such a procedure, of course, implies a state of statistical control in the processes leading to a reasonably well-behaved normal distribution for which averages and control limits can be defined. This situation can be said to be in effect for most transistors under current development.

However, for the old Type A unit, control simply was not in evidence, so that, in quoting figures on Type A's, ranges for commensurate fractions of the total family will be given. In order that symbols and terminology will be clear, it will be useful to review briefly the method of defining the linear characteristics of

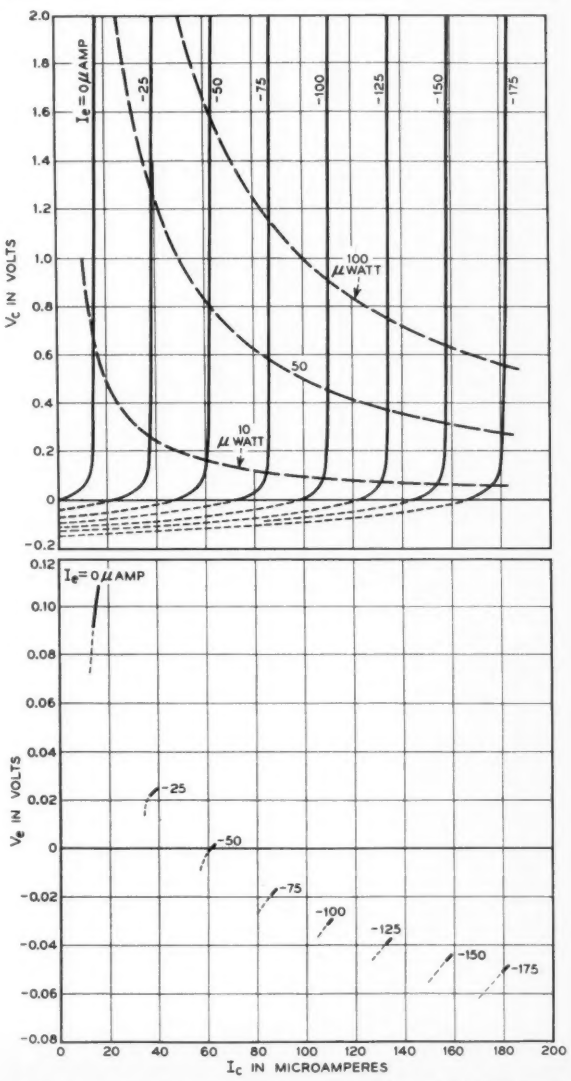
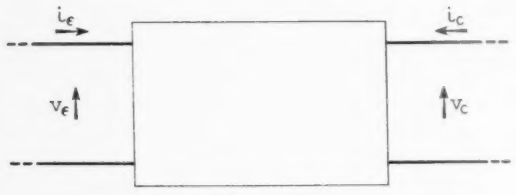


FIG. 9. Expanded plot of microwatt region of M1752 static characteristics.

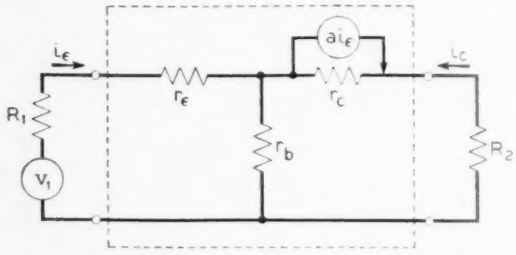
all transistors. In Fig. 10 is shown a generalized 4-pole network representing the transistor in which the input terminals are emitter-base and the output terminals are collector-base. Then, over a sufficiently small region of the static characteristics, the linear relations between the incremental emitter and collector voltages and currents may be represented by the pair of linear equations shown.[1] The coefficients are simply the open-circuit driving point and transfer impedances of the transistor or the slopes of the appropriate static characteristics at fixed d.c. operating currents. These equations may be represented by any one of a large number of equivalent circuits of which the one shown in Fig. 11 is perhaps currently most useful. In this circuit r_e is almost the a.c. forward impedance of the emitter barrier, r_c is almost the a.c. reverse impedance of the collector barrier, r_b is the feedback impedance of the bulk germanium common to both, and a is the circuit current gain representing carrier collection and multiplication, if any. It turns out this is almost equal to the current multiplication factor a of the collector barrier mentioned before. Average values of these elements for the Type A transistor are given in Fig. 11. In Fig. 12 are given the ranges of these parameters for the Type A as of September, 1949, and the control limits* for the same characteristics for new point-contact transistors now under development. For September, 1949, the ranges are taken about the average values shown in Fig. 11 for the Type A transistor. The control limits given for the present situation apply to a number of different types of point-contact transistors so that the present average values of these equivalent circuit elements depend upon the type of transistor considered. In Fig. 13 are given the average values of the characteristics of the M1729 point-contact video amplifier transistor that bears the closest resemblance to the older Type A transistor. By way of contrast are given some typical values of the elements for the M1752 junction transistor, which is not yet far enough along in its development to have design centers fixed or reliable dispersion figures available.



$$v_e = i_e z_{11} + i_c z_{12}$$

$$v_c = i_e z_{21} + i_c z_{22}$$

FIG. 10. The general linear transistor.



$\bar{r}_e$ = 250 OHMS $\quad \bar{r}_c$ = 20,000 OHMS

$\bar{r}_b$ = 250 OHMS $\quad \bar{a}$ = 2

FIG. 11. Equivalent circuit and Type A average element values.

ELEMENT	RANGE SEPTEMBER 1949	RANGE JANUARY 1952
a	4 : 1	±20%
r_c	7 : 1	±30%
r_e	3 : 1	±20%
r_b	7 : 1	±25%

FIG. 12. Reproducibility of point-contact linear characteristics.

TYPE	M 1729	M 1752
r_e	120	25
r_b	75	250
r_c	15,000	5×10^6
a	2.5	0.95

FIG. 13. Average characteristics of M1729 and typical characteristics of M1752 transistors.

As Ryder and Kircher have shown,[1] transistors in the grounded-base connection may be short-circuit unstable if $a > 1$ and r_b is too large, since r_b appears as a positive feedback element. The curve in Fig. 14 is a plot of the short-circuit stability contour when r_e and r_c have the nominal values of 700 and 20,000 ohms. Transistors having a and r_b sufficiently large to place their representative points above this contour will be short-circuit unstable—i.e., they will oscillate when short-circuited. Those having an $a - r_b$ point below the stability contour will be unconditionally stable under any termination conditions. The large unshaded rectangle bounds those values of a and r_b which were representative of the Type A transistor in September, 1949. It is apparent that the circuit user of Type A units had approximately a 50 per cent chance of obtaining a short-circuit unstable unit from a large family of Type A units. The smaller shaded rectangle bounds the values of a and r_b now realized in the M1729 transistor presently under development. Not only has the spread in characteristics been greatly reduced as shown, but also the design centers have been moved to a region for which all members of the M1729 family are unconditionally stable.

It is of interest to note that spreads of the order of ±20 to ±25 per cent are of the same magnitude as those dispersions now existing among the character-

* A.S.T.M. Manual, *Quality Control of Materials*, Part III, pp. 55–114, January, 1951.

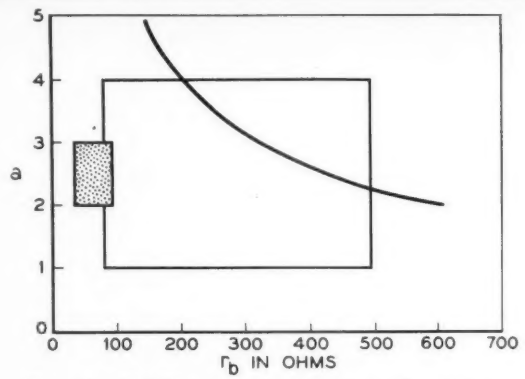


FIG. 14. Stability contour and ranges of a and r_b.

istics of presently available well-controlled electron tubes. These kinds of data on reproducibility of the linear equivalent circuit element values hold for practically all classes of point-contact devices now under development for CW transmission service. While it is too early to prove that such a situation pertains as well to junction transistors, there is every reason to expect similar results after a suitable development period.

(2.3) *Reproducibility of Large-Signal Characteristics for Pulse Application*

When electron devices are employed for large-signal applications, particularly those of switching and computing, it is well known that the characteristics must be controlled over a broad range of variables from cutoff to saturation. In September, 1949, little attempt was made to control such pulse use characteristics. In the intervening time, transistor circuit studies have proceeded to the point where it is possible to define certain necessary large-scale transistor characteristics that, if met, permit such transistors to be used interchangeably and reproducibly in a variety of pulse circuit functions such as binary counters, bit registers, regenerative pulse amplifiers, pulse delay amplifiers, gated amplifiers, and pulse generators. Moreover, it has been possible to meet these requirements on a developmental level with good yields in at least three types of point-contact switching transistors. The scope of this paper will not permit a detailed accounting of the technical features of this situation, and such an account will be forthcoming in future papers on these particular studies. However, a brief description of some of the more important pulse characteristics and their tolerances is certainly pertinent.

In practically all of the transistor pulse handling circuits examined to date, one characteristic common to all is the ability of the transistor, by virtue of its current gain, to present various types of two-state negative resistance characteristics at any one or all of its pairs of terminals. A typical simple circuit and corresponding characteristic is shown in Fig. 15 for the emitter-ground terminals when a sufficiently large value of resistance is inserted in the base to make the circuit unstable. In Region I, where the emitter is negative, the input resistance is essentially the reverse characteristic of the emitter as a simple diode. In Region II, as the emitter goes positive, alpha, the current gain rises rapidly above unity. If R_b is sufficiently large and alpha, the current gain, is greater than unity, the emitter-to-ground voltage will begin to fall because of the larger collector current increments driving the voltage of the node N negative more rapidly than the emitter current drop through r_e would normally carry it. This transition point is called the peak point. If then $a(r_b + R_b)$ is sufficiently large, in this sense, the input resistance may be negative in this Region II. When the internal node voltage has fallen to a value near that of the collector terminal, the "valley point" has been reached. At this point, the emitted hole current has reduced the collector inpedance to a minimum value beyond which a is essentially zero; the transistor is said to be saturated. From this point

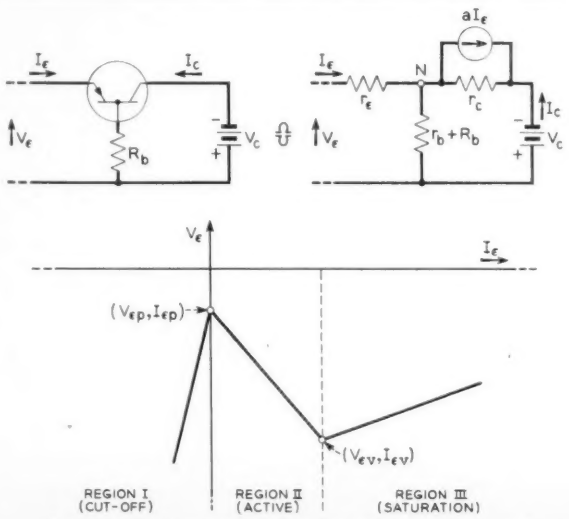


FIG. 15. Emitter-ground negative resistance circuit and characteristic.

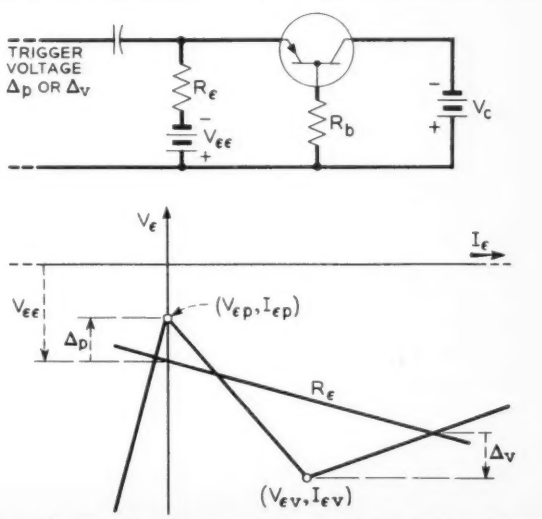


FIG. 16. Bistable circuit and characteristic showing trigger voltage requirements.

on, the input impedance again becomes positive and is determined almost entirely by the base and emitter impedances. By terminating the emitter-ground terminals in various ways with resistor-capacitor-bias combinations, such a network can be made to perform monostable, astable, or bistable functions. Under such conditions, the emitter current and, correspondingly, the collector current switch back and forth between cutoff and saturation values. For example, in Fig. 16 is shown a value of emitter bias and load resistance such that there are three possible equilibrium values of emitter current and voltage. It may be shown that the two intersections in Regions I and III are stable whereas that in Region II is unstable. Hence, if the stable equilibrium is originally in I, a small positive pulse Δ_p applied to the emitter will be enough to switch from stable point I to stable point II, and, conversely, $-\Delta_e$ will carry it from the high current point to the low current point. The circuit designer is interested in reproducing in a given circuit (with different transistors of the same type) the following points of the characteristic:

(1) The off impedance of the emitter—he desires that this be greater than a certain minimum.

(2) The peak point V_{ep}—he desires that this be smaller than a certain maximum.

(3) The value of the negative resistance—he desires that this be greater than a certain minimum.

(4) The valley point V_{es}, I_{es}—he desires that these be greater than certain minima.

(5) The slope in Region III—he desires that this be smaller than a certain maximum so that he may control it by external means.

It may be shown that these conditions can be satisfied for useful circuits by specifying certain maximum and minimum boundaries on the static characteristics. Fig. 17 is an idealized set of input or emitter characteristics. By specifying a minimum value for the reverse resistance in Region I, condition (1) above is satisfied. By specifying a maximum slope in Regions II and III, condition (5) is satisfied. Now refer to the idealized collector family of Fig. 18. By specifying a maximum value to V_{C3}, it is possible to ensure condition (4), and, by specifying a minimum value for r_{c0} condition (2) can be satisfied. Finally, in Fig. 19, by demanding that alpha, as a function of I_e, go through a transition from a negligible value (at small negative I_e) to a value well in excess of unity (at a correspondingly small positive value of I_e) and maintain its value well in excess of unity at large values of I_e, conditions (2) and (3) can be met.

In Fig. 20 are given the characteristic specifications that must be met by the M1689 bead-type switching transistor now under development. With these kinds of limits, circuit users find it possible to interchange such M1689 units in various pulse circuits and obtain overall circuit behavior reproducible to the order of about ±2 db.

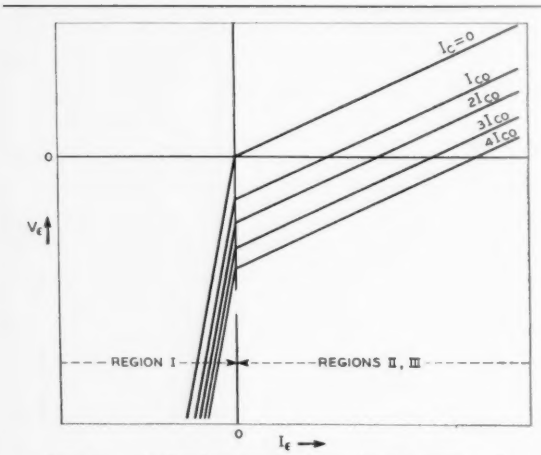


FIG. 17. Idealized emitter characteristics; slope = R_{II}.

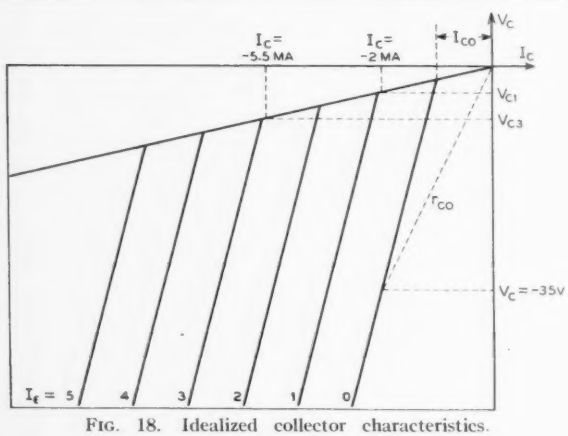


FIG. 18. Idealized collector characteristics.

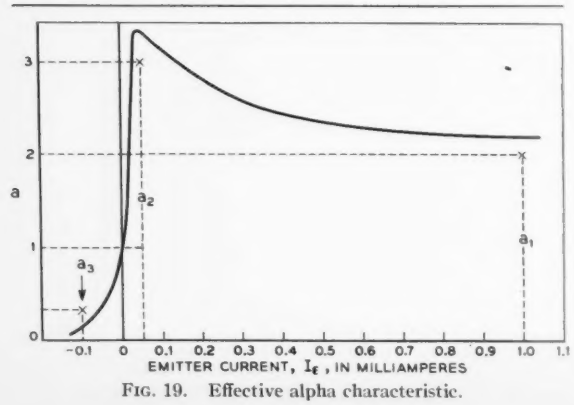


FIG. 19. Effective alpha characteristic.

(3) Reliability Status

(3.1) *Life*

Reliability figures of merit are not too well defined for electron tubes, and the same situation certainly holds at present for transistors. However, insofar as these quantities can be presently defined, Fig. 21 shows a comparison between the present status and that in September, 1949. Estimates of the half-life of a statistical family of devices are at best arbitrary and necessarily amount to extrapolations of survival

TEST	CONDITIONS	MINIMUM	MAXIMUM
r_{c0} – OFF COLLECTOR DC RESISTANCE	$V_c = -35$ V DC $I_e = 0$ MA DC	17,500 OHMS	—
V_{c1} – ON COLLECTOR VOLTAGE	$I_c = -2$ MA DC $I_e = 1$ MA DC	—	−3V DC
V_{c3} – ON COLLECTOR VOLTAGE	$I_c = -5.5$ MA DC $I_e = 3$ MA DC	—	−4V DC
OFF EMITTER RESISTANCE	$V_c = -10$ V DC	50,000 OHMS	—
ON EMITTER RESISTANCE R_{11}	$V_c = -10$ V DC $I_e = 1$ MA DC	—	800 OHMS
a_1	$V_c = -30$ V DC $I_e = 1.0$ MA DC	1.5	—
a_2	$V_c = -30$ V DC $I_e = +0.05$ MA DC	2.0	—
a_3	$V_c = -30$ V DC $I_e = -0.1$ MA DC	—	0.3
R_{12} – OPEN CIRCUIT FEEDBACK RESISTANCE	$V_c = -10$ V DC $I_e = +1$ MA DC	—	500 OHMS
R_{21} – OPEN CIRCUIT FORWARD RESISTANCE	$V_c = -10$ V DC $I_e = +1$ MA DC	15,000 OHMS	—
R_{22} – OPEN CIRCUIT OUTPUT RESISTANCE	$V_c = -10$ V DC $I_e = +1$ MA DC	10,000 OHMS	—

FIG. 20. Tentative characteristics for M1689 switching transistor.

RELIABILITY FIGURE OF MERIT	SEPTEMBER 1949	JANUARY 1952
AVERAGE LIFE	≐ 10,000 HOURS	> 70,000 HOURS
EQUIVALENT TEMPERATURE COEFFICIENT OF r_c	−1% PER DEG C	−¼% PER DEG C
SHOCK	?	> 20,000 G
VIBRATION	?	20 – 5000 CPS NEGLIGIBLE TO 100 G

FIG. 21. Reliability status.

curves, assuming that a known survival law will continue to hold.* In September, 1949, life tests on Type A units had been in effect some 4,000 hours. With the assumption of an exponential survival law, it was not possible, on the basis of a 4,000-hour test, to estimate the slope sufficiently accurately to warrant a half-life estimate in excess of 10,000 hours. These same Type A units have now run on life test for approximately 20,000 hours. With the more reliable estimate of survival slope now possible, the half life is now estimated to be somewhat in excess of 70,000 hours. It should be emphasized, however, that these are Type A units of more than 2 years ago made with inferior materials and processes. It is believed that those units under current development, being made with new materials and processes, are superior, but, of course, life tests are only a few thousand hours old. Although these new data are encouraging, it is still too early to extrapolate the data such a long way.

* Estimates of life, of course, depend upon definitions of "death." For these experiments, the transistors were operated as Class A amplifiers. A transistor is said to have failed when its Class A gain has fallen 3 db. or more below its starting value.

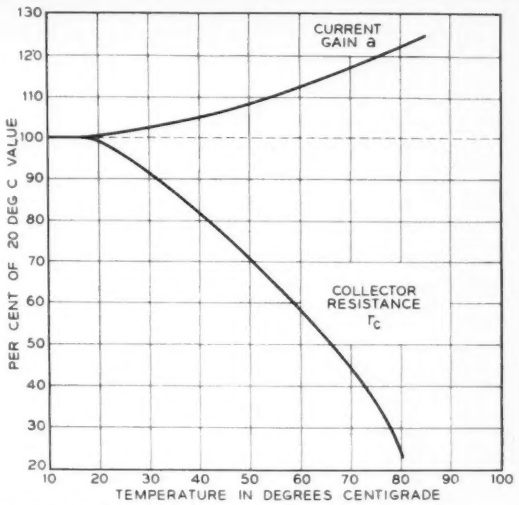


FIG. 22. Collector resistance and alpha vs. temperature for Type A transistor.

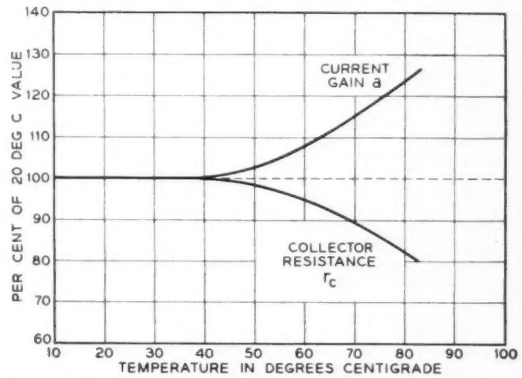


FIG. 23. Collector resistance and alpha vs. temperature for type M1729 transistor.

(3.2) *Temperature Effects*

Transistors, like other semiconductor devices, are more sensitive to variations in temperature than are electron tubes. In terms of the linear equivalent circuit elements, the collector impedance, r_c, and the current gain, a, are the most sensitive. Over the range from −40° to +80°C., the other elements are relatively much less sensitive. For Type A transistors, these temperaure variations in r_c and a are shown in Fig. 22. While these curves are definitely not linear, an average temperature coefficient for r_c of about −1 per cent per degree was estimated for the purpose of easy tabulation and comparison in Fig. 21.

Thus, for the early Type A, r_c fell off to about 20 to 30 per cent of its room temperature value when the temperature was raised to +80°C.; at the same time, a increased from 20 to 30 per cent over the same temperature range. Today, this variation has been reduced by a factor of about four for r_c in most point-contact types, the variations in the current gain being relatively unchanged. Fig. 23 illustrates the temperature dependence of r_c and a for the M1729 transistor

now under development. Again, for purposes of easy comparison in Fig. 21, the actual dependence of Fig. 23 was approximated by a linear variation, and only the slope is given in Fig. 21. For linear applications such as the grounded-base amplifier, the Class A power gain is approximately proportional to $a^2 r_c$; hence, the gain of such an amplifier will stay essentially constant within 1 or 2 db. over the temperature range from $-40°$ to $+80°$C. For pulse applications and important to d.c. biasing with point-contact transistors is the fact that the d.c. collector current (for fixed emitter current and collector voltage) will change at about the same rate as does r_c, the small signal collector impedance. Similar improvements have been made in these variations for switching transistors, and Fig. 24 is a series of graphs showing how the M1689 bead-type switching transistor changes the pulse characteristics defined in Fig. 20 with respect to temperature. For those switching functions examined to date, it is believed that these data mean reliable operation to as high as $+70°$C. in most applications and perhaps as high as $+80°$C. in others.

In junction transistors the laws of temperature variation are not so well established, the device being in a much earlier stage of development. Preliminary data indicate smaller variations in the small signal parameters such as a and r_c. On the other hand, variations in the d.c. current, particularly I_{c0}, are many times greater—of the order of 10 per cent per degree centigrade.* The only saving grace here is the fact that I_{c0} is normally much less than the actual operating value of I_c.

In summary, it may be said that, while significant improvements have been made in temperature dependence to the point where many applications appear feasible, it is not to be inferred that the temperature limitation is completely overcome. Much more development work of device, circuit, and system nature is required to bring this aspect of reliable operation to a completely satisfying solution.

(3.3) *Shock and Vibration*

With regard to mechanical ruggedness, current point-contact transistors have been shock tested up to 20,000 g with no change in their electrical characteristics. Vibration of point-contact and junction transistors over the frequency range from 20 to 5,000 cycles per sec. at accelerations of 100 g produces no detectable modulation of any of the transistor electrical characteristics—i.e., such modulation, if it exists, is far below the inherent noise level. At a few spot frequencies in the audio range, vibration tests up to 1,000 g accelerations similarly failed to produce discernible modulation of the transistor characteristics.

* I_{c0} is the collector current at zero emitter current.

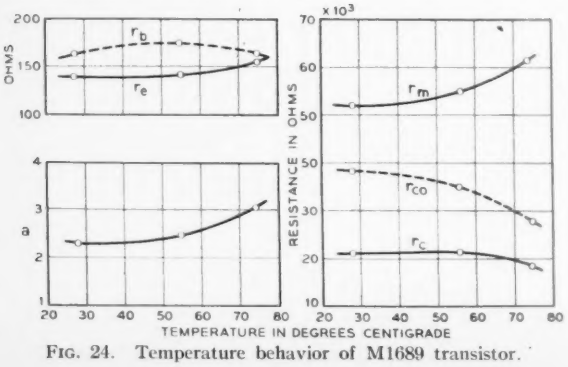


FIG. 24. Temperature behavior of M1689 transistor.

MINIATURIZATION FIGURE OF MERIT	TYPE A SEPTEMBER 1949	JANUARY 1952	NEW DEVELOPMENT TYPE
VOLUME	$1/50$ IN^3	$1/2000$ IN^3	POINT - M1689
		$1/500$ IN^3	JUNCTION - M1752
MINIMUM COLLECTOR VOLTAGE FOR CLASS A OPERATION	30 V	2 V	POINT - M1768, M1734
		0.2 V	JUNCTION - M1752
MINIMUM COLLECTOR POWER FOR CLASS A OPERATION	50 MW	2 MW	POINT - M1768
		10 μW	JUNCTION - M1752
CLASS A EFFICIENCY	20%	35%	POINT - M1768, M1729
		49%	JUNCTION - M1752

FIG. 25. Miniaturization in space and power drain.

(4) MINIATURIZATION STATUS

(4.1) *Space Requirements*

In smallness of size, the transistor is entering new fields previously inaccessible to electron devices. The cartridge structure (see Fig. 25), such as the Type A, has a volume of $^1/_{50}$ cu.in., compared to about $^1/_8$ cu.in. for a subminiature tube and about 1 cu.in. for a miniature tube. Under current development, the M1689 bead point-contact transistor has electrical characteristics substantially similar to the M1698 cartridge switching unit but occupies only about $^1/_{2000}$ cu.in.† The M1752 junction bead transistor has a volume of about $^1/_{500}$ cu.in., but this may be reduced to the same order as the point-contact bead if necessary. For further substantial size reductions in equipment, the next move must comprise the passive components. It should be pointed out that the low voltages, low power drain, and correspondingly lower equipment temperatures should make possible further reductions in passive component size.

(4.2) *Power Requirements*

The transistor, of course, has the inherent advantage of requiring no heater power; moreover, significant advances have been made in the past 2 years in reducing the collector voltage and power required for practical operation. Consider the minimum collector voltage, for which the small-signal Class A gain is still within 3 to 6 db. of its full value. In September, 1949,

† The M1698 transistor is a cartridge-type point-contact transistor with electrical characteristics designed for switching and pulse-handling functions. This unit is proving useful in the laboratory development of new circuits or in cases where miniature packages are not necessary.

the Type A transistor could give useful gains at collector voltages as low as 30 volts. Today, several point-contact devices (M1768 and M1734) perform well with collector voltages as low as 2 to 6 volts even for relatively high-frequency operation. One junction transistor, the M1752, can deliver useful gains at collector voltages as low as 0.2 to 1.0 volt. Under these same conditions, the minimum collector power for useful gains may be as low as 2–10 milliwatts for point-contact devices and as low as 10–100 microwatts in the case of the junction transistors.* Class A efficiencies have been raised for the point-contact devices to as high as 30–35 per cent and, for junction transistors, this may be as high as 49 per cent out of a maximum possible 50 per cent. Class B and C efficiencies are correspondingly close to their theoretical limiting values.

(5) Performance Status

Exact electrical performance specifications for the transistor depend, of course, upon the intended applications and the type of transistor being developed for such an application. These types are beginning to be specified, and, in fact, they are already so numerous that mention of only a few salient features of some of them will be attempted. Bear in mind, as was pointed out before, that no one transistor combines all the virtues any more than does any one tube type. Fig. 26 attempts to compare the progress made in several important performance merit figures by development of several point-contact and junction types during the last 2 years. Again the reference performance is that of the Type A as of September, 1949.

Some switching and transmission applications need transistors having high current gain. By going to a point-junction structure, useful values of a as high as 50 are now possible with laboratory models.

For straight transmission applications, the single-stage gain of point-contact types (M1768, M1729) has been increased to 20–24 db. whereas for the M1752 junction type, the single-stage gain may be as high as 45–50 db.

For high-sensitivity low-noise applications, the point-contact devices have been improved to have noise figures of only about 40–45 db., whereas the M1752 *n-p-n* transistor has been shown to have noise figures in the 10–20 db. range. All such noise figures are specified at 1,000 cycles per sec., and it should be remembered that they vary inversely with frequency at the rate of about 11 db. per decade change in frequency.

For video, intermediate frequency, and high-speed switching applications, measurable improvement has been attained in the frequency response. For video amplifiers up to about 7 mc. the M1729 point-contact transistor is capable of about 18–20-db. gain per stage. For high-frequency oscillators and microsecond pulse switching, the M1734 point-contact transistor is under development. Preliminary models of 24-mc. I.F. amplifiers using the M1734 have been constructed in the laboratory, these amplifiers having a gain of some 18–24-db./stage and a band width of several megacycles. However, more work needs to be done on the M1734 to reduce its feedback resistance. For pulse-handling functions, such M1734 units work nicely as pulse generators and amplifiers of $^1/_2$-microsecond pulses, requiring only 6–8 volts of collector

* In some special cases, depending upon the application, practical operation may be obtained for as little as 0.1–1.0 microwatt.

PERFORMANCE FIGURE OF MERIT	TYPE A SEPTEMBER 1949	JANUARY 1952	NEW DEVELOPMENT TYPE
a – CURRENT GAIN	5X	50X	JUNCTION
SINGLE STAGE CLASS A GAIN	18 DB	22 DB	POINT – M1729, M1768
		45 DB	JUNCTION – M1752
NOISE FIGURE AT 1000 CPS	60 DB	45 DB	POINT – M1768
		10 DB	JUNCTION – M1752
FREQUENCY RESPONSE f_c	5 MC	7–10 MC	POINT – M1729
		20–50 MC	POINT – M1734
CLASS A POWER OUTPUT	0.5 WATT	2 WATTS	JUNCTION
SWITCHING CHARACTERISTICS	NONE	GOOD	POINT – M1698, M1689 M1734
FEEDBACK RESISTANCE r_b	250 OHMS	170 OHMS	POINT – M1729
$\frac{\text{LIGHT}}{\text{DARK}}$ PHOTOCURRENT RATIO	2:1	20:1	JUNCTION – M1740

Fig. 26. Performance progress.

1. 4 DIGIT REVERSIBLE BINARY COUNTER
2. 6 DIGIT ANGULAR POSITION ENCODER
3. 6 DIGIT GRAY – BINARY TRANSLATOR
4. 5 DIGIT SHIFT REGISTER
5. 2 WORD SERIAL ADDER

Fig. 27. System functions tested.

DEVELOPMENT PACKAGE TYPE	PACKAGE FUNCTION	DEVELOPMENT TRANSISTOR, DIODE TYPES USED
M 1731-1	REGENERATIVE GATE	M 1689 M 1727
M 1732-1 M 1736 M 1790	BIT REGISTER	M 1689 M 1727 M 1734
M 1733-1 M 1792	PULSE AMPLIFIER	M 1689
M 1735-1 M 1747-1 M 1748-1 M 1751-1 M 1751-2 M 1751-3	DIODE GATE	M 1727 400 A
M 1745-1 M 1791	BINARY COUNTER	M 1689 400 A
M 1749-1	PHOTOCELL READOUT	M 1740
M 1746-1	DELAY AMPLIFIER	M 1689

Fig. 28. Development transistor-circuit packages.

FIG. 29. Bit register package.

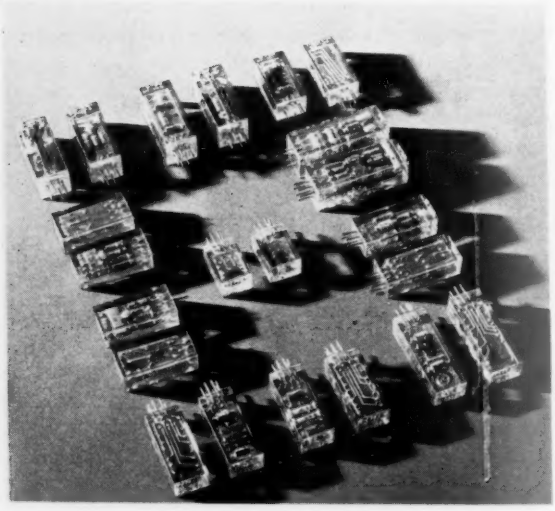


FIG. 30. Package construction illustrated.

voltage and 12–20 microwatts of collector power per stage. The amplified pulses can have amplitudes as large as 4–5 volts out of a total collector voltage of 6 volts and rise times as little as 0.01–0.02 microsecond.

By increasing the thermal dissipation limits of junction transistors, the Class A power output has been raised to 2 watts in laboratory models. This, however, does not represent an intrinsic upper limit but rather a design objective for a particular application.

Characteristics suitable for switching are now available in the M1698, M1689, and M1734 point-contact types, as previously described, but this is a continually evolving process and more work certainly remains to be done. At present, it is possible to operate telephone relays requiring as much as 50 to 100 milliamperes with M1689 and M1698 point-contact transistors.

New junction-type phototransistors[5] represent a marked advance over the earlier point-contact type.[6] While theire quantum efficiencies are not as high as those of the point-contact types, nevertheless the light/dark current ratios are greatly improved and the collector impedance has been raised 10–100 times, thus making possible much greater output voltages for the same light flux.

(6) Some Selected Applications

(6.1) *Data Transmission Packages*

To determine the feasibility of applying transistors in the form of miniature packaged circuit functions, several of the major system functions of a pulse code data transmission system have been studied. This investigation has been undertaken under the auspices of a joint services engineering contract administered by the Signal Corps.

It was desired that these studies should lead to the feasibility-development of unitized functional packages combining features of miniaturization, reliability, and low power drain. Accordingly, it was necessary to carry on in an integrated fashion activities in the fields of system, circuit, and device development to achieve these ends. In particular, circuit and system means have been developed to perform with transistors the functions of encoding, translation, counting, registering, and serial addition. The M1728 junction diode, M1740 junction photocell, and M1689 bead-switching transistor are direct outgrowths of this program and are the devices used in the circuit packages.

At this point, the major system functions shown in Fig. 27 have been achieved with interchangeable transistors. These major system functions are in turn built up of some seven types of smaller functional packages listed in Fig. 28. The end result of this exploratory development can be said to have demonstrated the feasibility of such a data transmission system in the sense that a workable (though not yet optimal) system can be synthesized from reproducible transistor-circuit packages that have been produced at reasonable yields and with reasonable (though not yet complete) service reliability. Further development work would be needed in all phases to make such a system of packages suitable for field use. It is estimated that the present laboratory model requires about one-tenth the space and power required to do the same job with the present tube art. Fig. 29 shows a photograph of a transistor bit-register package, and Fig. 30 shows another photograph of such packages showing both sides of the various types employed.* Actual final packages would probably not use such clear plastics, and Fig. 31 shows some packages in which the plastic has been loaded with silica to increase its strength and thermal conductivity. The assembly in Fig. 31 consists of a six-digit position encoder at the left, followed by six regenerative pulse

* The Auto-Assembly Process used in the construction of these packages is a Signal Corps Development.

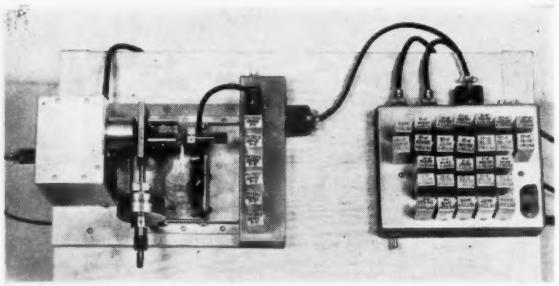


FIG. 31. Laboratory model of encoder-translator-register using transistor packages.

amplifiers that in turn feed a six-digit combined translator-shift register.

(6.2) *N-P-N Transistor Audio Amplifier and Oscillator**

To the right in Fig. 32 is shown a transformer coupled audio amplifier employing two M1752 junction transistors. This amplifier has a pass band from 100–20,000 cycles per sec. and a power gain of approximately 90 db. Its gain is relatively independent of collector voltage from 1–20 volts, only the available undistorted power output increasing as the voltage is increased. At a collector voltage of 1.5 volts, it draws a collector current of approximately 0.5 milliampere per unit for a total power drain of 1.5 milliwatts. Under these conditions it will deliver Class A output power of about 0.7 milliwatt. The noise figure of such an amplifier has been measured to be in the range from 10–15 db. at 1,000 cycles per sec., depending upon the operating biases.

To the left of Fig. 32 is shown a small transistor audio oscillator having a single M1752 transistor, a transformer, and one condenser. To see just how little power was the minimum necessary to produce stable oscillations, such an oscillator was tried at increasingly lower collector supply voltages. It was found that stable oscillations could be maintained down to collector supply voltages as low as 55 millivolts and collector current as low as 1.5 microamperes for a total drain of 0.09 microwatt.

(7) SUMMARY

With respect to reproducibility and interchangeability, transistors now under development appear to be the equal of commercial vacuum tubes.

With regard to reliability, transistors apparently have longer life and greater mechanical ruggedness to withstand shock and vibration than most vacuum tubes. With regard to temperature effects, transistors are inferior to tubes, and present upper limits of operation are 70–80°C. for most applications. This restriction is often reduced in importance by the low power consumption that results in low equipment self-heating. This, however, is the outstanding reliability defect of transistors.

With regard to miniaturization of space and power supply requirements, the comparison figures are so great as to speak for themselves. Operation with a few milliwatts is always feasible, and, in some cases, operation at a few microwatts is also possible.

With regard to performance range, it is believed that the above results imply the following tentative conclusions:

(1) In pulse systems (up to 1–2 mc.- repetition rates) transistors should be considered seriously in comparison to tubes, since they provide essentially equal functional performance and have marked superiority in miniature space and power. Bear in mind that in some reliability figures they are superior, whereas, in the matter of temperature dependence, they are inferior to tubes.

(2) In transmission at low frequencies (< 1 mc.) essentially the same conclusions are indicated, primarily because of junction transistors. In the range from 1–100-mc., tubes are currently superior in every functional performance figure (except perhaps noise and band width) so that for transistors to be considered for such applications, much greater premium must be placed on miniaturization and reliability than for the first two applications areas.

Thus, it might be assumed that, even though there are many outstanding development problems of a circuit and device nature to be solved, it is appropriate for circuit engineers to explore seriously the application possibilities of transistors in the hope not only to build better systems but also to influence transistor development toward those most important systems for which their intrinsic potentialities best fit them. It should not be inferred that all important limitations have been eliminated nor, on the other hand, that the full range of performance possibilities has been explored.

If one remembers the history of engineering research and development in older related fields, it seems apparent that a relatively short time has elapsed since the invention of the first point-contact transistor. Already, new properties and new types of devices are under study, and some have been achieved in the laboratory. It therefore is possible, and certainly stimulating, to infer that more than a single new component

(*Continued on page 87*)

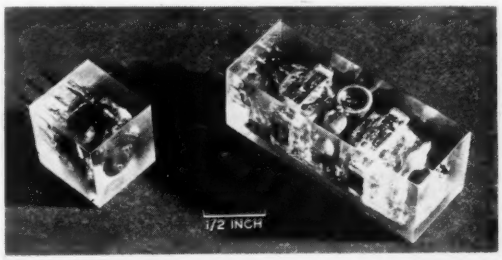


FIG. 32. Packaged oscillator and amplifier using junction transistors.

* The material of Section (6.2) represents a brief summary of some work by Wallace and Pietenpol described more completely in reference 4.

All-Weather Operation Problems

Some Notes on I.A.S.-I.R.E.-I.O.N.-R.T.C.A. Electronics in Aviation Symposium

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TO BRING INTO MORE BOLD RELIEF the content of the morning and afternoon meetings on "Electronics in Aviation" of January 30, the Institute of Aeronautical Sciences, the Institute of Radio Engineers, the Institute of Navigation, and the Radio Technical Commission for Aeronautics joined hands in presenting this evening Symposium. Since the morning and afternoon meetings comprised, largely, technical papers covering the engineering or theoretical approaches to the place of electronics in aviation, it was decided that in this concluding evening session the emphasis should be placed on the end results thereof —the actual operational use and applications of electronics to all-weather flight. Each organization actively participating in current all-weather flight developments and operation was invited to participate. As a result the Symposium panel was composed of:

Captain E. A. Cutrell, Eastern Region, American Airlines, Inc. (Representing the Airline Pilots Association)
Captain L. F. Dodson, USN, Naval Operations
Captain J. F. Gill, Chief Pilot, Eastern Air Lines, Inc.
Captain A. E. Jenks, Chief, Flight Inspection Division, Office of Federal Airways, CAA
Claude F. King, Deputy Commissioner—Airports, City of Cleveland (Representing the Airport Operators Council)
Cole H. Morrow, Chairman, Board of Directors, Corporation Aircraft Owners Association, and Chief Plant Engineer, J. I. Case Company
E. A. Post, Superintendent, Navigational Aids, United Air Lines, Inc.
Captain Robert B. Roe, Engineering Department, Head for Flight Operations, Sperry Gyroscope Company
Captain S. P. Saint, Director, ANTC Division, Air Transport Association
Captain James L. Anast, USAF, All-Weather Section, Flight Test Division, Wright Air Development Center
Captain M. G. Beard, Chief Engineer, American Airlines, Inc.

Captain L. V. Berkner, USNR, President of Associated Universities, Inc., the operators of Brookhaven Atomic Laboratories, was selected to chairman this panel. He has had lengthy commercial and naval experience in aviation and electronics. As an active pilot, he has participated energetically and effectively for many years in the resolution of the many problems of all-weather flight.

Captain Berkner concisely and effectively reviewed the current critical need for safe and reliable all-weather scheduled flight in his own and many other businesses. He then introduced the panel members, thereafter directing one question to each. These questions were replied to, in turn, with floor questions and discussion withheld until all panel members had answered their particular questions. The questions put to this panel and the individual panel member replies as well as floor questions and discussion were noted as follows:

Chairman's question to Capt. E. A. Cutrell:

"What do you believe is needed to improve the safety and reliability of air-line operations?"

Captain Cutrell in reply requested:

* Assistant to Director—Flight

"(a) Visual aids. By that is meant national standardization and installation of essential high-intensity approach lighting, runway threshold lighting, runway lighting, and runway (paint) marking.

"(b) Electronic equipment required to provide for a minimum of two-way approaches to a given landing area.

"(c) Electronic automatic pilot plus automatic approach equipment on the aircraft.

"(d) Terminal area radar traffic control.

"(e) Better aircraft cockpit lighting.

"(f) Reduction of pilot work load during an approach.

"(g) FIDO.

"(h) Better coordination of Federal Government bureaus—more service with less restricting regulations.

"(i) Operation of freight only flights under all-weather conditions to service test thoroughly the suggested devices and to develop satisfactory pilot techniques and confidence.

"(j) Construction or implementation of terminals such that aircraft airfoils can be kept clear of falling snow or freezing rain while aircraft is at ramp."

Chairman's question to Capt. L. F. Dodson:

"Has the Navy found that the jet-powered aircraft, referring particularly to its higher speed and critical fuel situation, presents any insurmountable problems with respect to navigation and traffic control procedures of the kind currently envisioned by the Air Coordinating Committee through its implementation of Working Group 5's proposals?"

Captain Dodson stated that the U.S. Navy has not had sufficient experience as yet to answer this question satisfactorily. He expressed the belief that SWG-5 had planned as practically as possible to supply the optimum required. He noted that U.S. Navy jets had participated at the USAF Dayton, Ohio, test and demonstration of SWG-5 implementation and had no difficulty.

Chairman's question to Capt. J. F. Gill:

"What visual aids are available for immediate application, and what other visual aids could stand some development?"

Captain Gill stated that all currently desired facilities are immediately available, and industry has agreed among themselves on details of the requirements comprising: (a) a single centerline approach light configuration; (b) Linear bar light units to be located 100 ft. apart for a maximum of 3,000 ft. along the approach path to the runway threshold; (c) krypton type of condenser discharge light units to be located adjacent to each linear bar unit, these flashers to be discharged in sequence from the outer to the inner end of the approach light system at a rate of 120 times per minute; (d) a transverse Linear light bar five times the length of the individual Linear light units to be located exactly 1,000 ft. out from end of runway; (e) for civil air transport use a well-defined and lighted "over-run" area of 200 ft. just prior to reaching the first hard surface usable runway plus adequate distinctive runway threshold lighting and marking; (f) high-intensity runway lighting (it was indicated that current needs are for standardization and implementation); and (g) Federal funds for the desired facilities.

Chairman's question to Capt. A. E. Jenks:

"How far can a pilot trust the currently used monitor equipment and procedures with respect to 'Fail-Safe' operation of I.L.S. and V.O.R. facilities?"

Captain Jenks reported that the CAA monitor system reliability is extremely good and that its outage is about 0.023 per cent of time by current records. He stated he believed the CAA "modernized" monitor of I.L.S. is good—a pilot can trust it to a high degree. He noted that CAA realizes this equipment is not perfect and stated they have been, are, and will continue, trying to improve it. He stated the I.L.S. localizer monitor is designed to hold the localizer course within 0.2°. It was stated that V.O.R.'s are presently being monitored at two course positions and cannot be monitored for all 360 courses. Jenks stated that V.O.R. monitors have failed a few times but that the overall usefulness and dependability of the V.O.R. is a vast improvement over the older four-course L/MF range facilities.

Chairman's question to Claude F. King:

"How far will the airport itself go in providing the visual aids mentioned as being desired by Gill and electronics aids mentioned by Cutrell?"

Mr. King noted that municipalities have been forced by withdrawals of federal funds to place airports on a paying basis; therefore, his first answer to this question obviously should be "no!"—following which he would then consider the many angles of the individual situation. He stated that the airport operators greatly need acceptable, satisfactory federal standards on airports and their facilities. He expressed the belief that civil airports would provide the requested runway facilities and implementation as soon as national standards thereon are established, but he felt approach lights and electronic aids to approach should be considered as federal en route facilities and supplied by CAA. He stated the airport operator especially desires establishment of national standards on runway widths. He also explained that airport operators are presently handicapped by lack of, or inadequate planning on, specifications for construction of new CAA Control Towers. He complained of failure of the Federal Government to match available local funds for airport construction. In closing his comments, Mr. King stressed the possibilities of the airport itself becoming a real bottleneck to aviation expansion because of current restrictions on availability of federal funds.

Chairman's question to Cole H. Morrow:

"How far will a majority of corporation- or executive-owned or operated aircraft users go in the way of aircraft equipment and qualification of pilots for all-weather operation?"

Mr. Morrow called to attention that already 98 per cent of the Corporation Aircraft Owners Association multiple-engined aircraft are equipped for V.O.R. operation, 92 per cent being equipped for I.L.S. and V.O.R. operation. He stated that C.A.O.A. aircraft pilots were well qualified—they follow "manuals" not memories. He noted that some 4,000 airports in the United States are presently used by C.A.O.A. against the 400 currently served by domestic air carriers. He stated that C.A.O.A. desires many of the 3,600 presently unequipped fields to be implemented for all-weather flight, and they are looking forward with much interest to the potentialities of DME/R-Theata computer off-set course operation to these fields. He also noted that C.A.O.A. is presently the largest user of Zero Readers. In concluding his reply, he stated that C.A.O.A.'s only concern is "When will better equipment be available?"

Chairman's question to E. A. Post:

"Just how far can one trust the aircraft 'flag alarms' with respect to I.L.S. and V.O.R. operation?"

Mr. Post stated that flag alarms can be trusted "too far" and that many pilots do not realize the several weaknesses of these devices. He noted that when using an I.L.S. the aircraft flag alarms will not display displaced courses resulting from partial (and sometimes not complete) failures of the aircraft receiver 90–150 cycle filter components or circuits. He expressed the belief that recent research and development work may permit some improvement of this condition. He also stated that these flags normally will not show displaced V.O.R. courses and that all users of the airspace are therefore looking forward anxiously to the day when someone develops better methods of cockpit checking of V.O.R. courses.

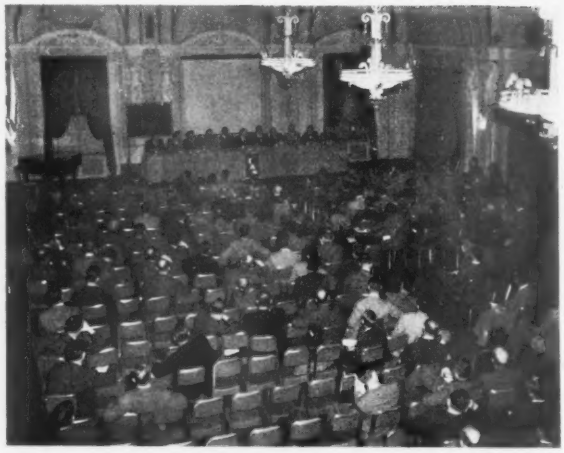
Chairman's question to Capt. Robert B. Roe:

"Assuming aircraft are equipped for automatic flight and approach and that we have the aids requested by Gill and Cutrell, do you believe the average air-line pilot would be able to approach automatically and land visually without much effect from weather?"

In reply Captain Roe stated that a recent CAA-Sperry tabulation of some 13,000 air carrier I.L.S. straight-in approaches made during 1949 and 1950 with weather of 900 ft. ceiling and below disclosed the following performance: With 500 ft. ceiling and 1 mile visibility—10 per cent misses. With 500 ft. ceiling and $^1/_2$ mile visibility—25 per cent misses. With 400 ft. ceiling and $^1/_2$ mile visibility—30 per cent misses. He stated that he believes utilization of automatic approach equipment would reduce such misses to less than 5 per cent. In concluding a general discussion of the factors affecting all-weather flight, Captain Roe stated his answer to the question was "yes."

Chairman's question to Capt. S. P. Saint:

"Assuming the experimental Washington terminal area radar traffic control works out as planned: Will aircraft then be able to land or depart as rapidly under I.F.R. as if under V.F.R. conditions?"



Captain Saint reported that five elements now limit I.F.R. capacity: (a) faulty sequence of landings, (b) coordination of ATC controllers, (c) nonradar separation standards, (d) landing interval control, and (e) airport ground control.

He noted that terminal area radar traffic control will take care of (a). He expressed the belief that developments now under way will provide the required answer to (b) soon. He stated that the present system at Washington takes care of (c) and (d). He referred to Claude F. King's remarks on resolution of (e)—that this depends upon availability of federal program and funds. Captain Saint stated that work accomplished to date at Washington indicates clearly that all aircraft involved must have radar beacons to provide all-weather and safe radar ATC.

Chairman's question to Capt. James L. Anast:

"How satisfactory, operations and maintenance-wise, do you believe cross-wind landing gear will be for multiple-engined transport aircraft, and do you believe such gear may improve the efficiency or safety of all-weather landings?"

Captain Anast stated that USAF is now sufficiently satisfied with cross-wind landing gear that it is being ordered for new multiple-engined tactical aircraft. He stated that the current service test installation on a C-54 castors 15° can be utilized with free or locked castor and locks automatically in normal position. He also stated this gear is extremely simple and presents no foreseeable problems in its final development and application. He predicted such gear and the advantages thereof could easily be available within 5 years if its procurement were pushed.

Chairman's question to Capt. M. G. Beard:

"What is the aviation industry doing, particularly what are they accomplishing in the way of standardizing aircraft flight instrumentation to provide our pilots a more standardized and usable end result?"

Captain Beard stated that the industry now has SAE-7 working diligently on cockpit standardization. He reported that this group's "recommended practices" on cockpit and instrument lighting was recently released and will be made an industry standard after a

reasonable period of trial application. He reported that this group's recommended standard on cockpit controls will be released shortly; also he believes this group will have obtained industry agreement on a standard transport instrument panel layout by the summer of 1952.

Dr. Warner of I.C.A.O. asked from the floor, "How far does the panel believe automatic approach equipment should be followed?" Captain Roe replied that he believes it safe to use automatic approach equipment to lowest allowed minimums. Captain Gill stated he believes it satisfactory to use such equipment to 100 ft. above and 1/4 mile from end of runway—the pilot at that point having sufficient visual aids to safely complete a "visual" landing. Gill also stated it was his opinion that the pilot requires a minimum of three seconds of visibility prior to touch-down. Captain Roe explained the I.A.T.A.-I.C.A.O. "critical altitude" concept of operations versus the currently used "ceiling and visibility" minimums.

Richard Mock of Lear, Inc., speaking from the floor, urged utilization of electronic automatic approach equipment for all aircraft approaches to debug the electronic-electric equipment and build up pilot confidence. Captain Cutrell commented that only about one in ten approaches of routine operation would permit simulated automatic approaches because of variables in wind direction, noise abatement, etc.

Captain Baker, Trans Canada Airlines, speaking from the floor, reported that, using one fully automatic DC-4, TCA had found that they could go down to between 150 and 100 ft. above ground with the same safety as currently obtained on manual operation with 300-3/4 minimums. He expressed the belief that it was unsafe to go below approximately 100 ft. because of glide slope instability and critical pull-out altitude of currently used aircraft. He stated he did not like the high approach speeds and control inflexibility of current transport aircraft types.

Dr. T. P. Wright, Cornell Laboratories, Inc., arose and stated he had heard comments from a Berlin airlift G.C.A. controller that G.C.A. should not be used as an I.L.S. monitor—one or the other, G.C.A. or I.L.S., should be used alone. Captain Saint replied defending strongly the current U.S. practice of using both—allowing for radar weather effects and lack of air-borne radar beacons. He stated his belief that G.C.A. and I.L.S. used together provide several times the safety of either used alone. Captain Berkner inquired as to the utility of air-borne radar and ground beacons to which Captain Saint replied that he believes these facilities have real future possibilities. Captain Gill reported that he favored radar overlaying the track of I.L.S.

A member of the audience, name unknown, questioned the desirability of canceling present C.A.R. "look-see" restrictions. E. A. Post replied, stating his belief that every pilot should be permitted a "look-see." Captain Cutrell commented that he believes take-off limits could be appreciably reduced without any decrease of operational safety. Captain Jenks stressed the desirability of providing pilots with more current and more continuous reports on weather observations made at the end of the runway being approached. He stated he believes it essential to develop means of measuring accurately from the ground slant visibility as viewed by the pilot from the normal approach path and providing this intelligence instantaneously to the pilot. Another member of the audience questioned the value of fog dispersal (FIDO) developments. Captain Gill replied that he believes FIDO valueless for the majority of domestic civil airports. He stated he does not like the turbulence created by FIDO operation and does not believe the cost of FIDO can be justified.

Another member of the audience questioned the safety aspects of the "nine-story high CAA Control Tower at New York International Airport." Another member of the audience speaking from the floor stated that this tower was simply a part of the ultimate New York International Airport Terminal Building; when this building is complete, this tower will be surrounded thereby. Claude F. King stated that changed flight procedures have changed conceptions of airport obstructions and that if runways and approaches thereto are clear, the airport obstructions present little or no problem. Captain Beard concurred with Mr. King, expressing belief that control towers should be in the middle of the airport landing area. Captain Anast concurred, stating that more precise flying of today and tomorrow will greatly reduce the hazards of such towers.

Captain Hal Henning of General Motors Corporation inquired (a) how dual V.H.F. navigational receivers (air borne) tie in with automatic approach and (b) when V.O.R. may be used for lateral separation of I.F.R. traffic. Mr. Post replied to (a) that this presents no problem except in aircraft system wiring. He believes the pilot will use one receiver to monitor or for supervision while the second receiver is being used to activate auto-approach equipment. In replying to (b), he stated he believes all aircraft involved must have dual V.O.R. receiver systems before any lateral I.F.R. A.T.C. separation can be accepted.

The audience's interest in this Symposium was very high. It was obvious that this meeting could have gone on successfully into the wee hours of the next morning—if the Chairman had seen fit to so do. It is believed this Symposium was one of the highlights of the 20th Annual Meeting of I.A.S.

Integrated Instrumentation for Modern Aircraft

LYNN S. BEALS, JR. (MC), USN*
Office of Naval Research

IN ACCEPTING YOUR INVITATION to speak at this session on "Problems Encountered in Today's High Speed Flights" with particular reference to instrumentation, I accepted the challenge to bring you something new, something worth listening to, something worth taking away with you, and something you could use in your professional lives. To achieve these high hopes, I must take some liberties with the implicit meaning of this paper's title and admit at the outset that I will not simply report one more highly specialized research result, thus adding to the world's knowledge by that famous "jot or tittle." Instead, I will report to you some of the deductions arrived at in my philosopher's easy chair as I have regarded with objective detachment the changing scene of research on aviation matters over the years and the manner in which it has been related to the practical operating problems.

Using a familiar corollary, if we assign the symbol ω to research results that push our barrier of the unknown a little farther away, I could properly say my concern is with $\dot{\omega}$ and $\ddot{\omega}$—and especially the latter. In addition to concern with the rate of research and the means for accelerating it, however, I am deeply dedicated to the purpose of assuring its meaningfulness. My objective, as a matter of fact, in this presentation is to demonstrate how I believe more meaning and practical significance can be derived from our research efforts.

We meet today to discuss the problems of instrumentation in today's high-speed flight. Most of us know the nature of these problems but too little of how to solve them; otherwise, we would not find it imperative to bring to bear such a mass of diverse expert talent. Frankly, I am afraid we must admit that today's problems, to a large measure, exist because of yesterday's failures, be whatever sort they are. Tomorrow's problems will be the result of today's inadequacy unless we prepare now to presolve them.

Such attempts at presolving are in fact now being made, as you have undoubtedly seen in the Press, at least on the part of the biosciences group. In the middle of November, 1951, the Air Force held a several-day conference on the subject of "Space Medicine" or how to support life in interplanetary space travel.

There may be a few instrument problems that will need solution for this space travel, but perhaps the instruments will be much more like astronomical equipment than the needle-and-ball. Compared with the magnitude of problems associated with travel through space (I hesitate to call it "flight"), the problems of today's high-speed aircraft seem somewhat pedestrian. They are, however, our real and very immediate problems, and we must find better ways of solving them soon, or five years from now space travel specialists will be accusing us of failure to think far enough into the future.

As Americans we have never prided ourselves upon our philosophical or logical abilities but rather have basked in a reputation for inventiveness. Our Patent Office files bear witness to this. Nationally we have believed we could invent our way out of industrial and technical difficulties, even economic problems. Specifically, this belief applied to the development of the airplane has led us straight into the present dilemma, where we stand a fine chance of inventing the pilot straight out of the aircraft and actually have in some cases.

The piling of one cockpit invention on another over the years has made the airplane an increasingly complex machine to the point where man is not always capable of matching the performance of the machine he operates.

Certainly now is the time to tread softly in proposing solutions based on more invention, lest the camel's back be broken and airplanes become too complex for human operation. It is, on the other hand, well past the time when we should examine our methods to see whether they can account for the situation in which we now find ourselves. Without going into details of a sort far better known to you who have been closely associated with them than to me, it appears that two factors have produced most of the problem. These are, first, that cockpit elements have been designed and developed by many different groups independent of each other and disinterested in each other's problems until they meet at the mock-up conference, and, second, that each new technical development that has extended the capacities of the aircraft has increased the complexity of the indicator display, the communications equipment, the aircraft controls, the specialized electronic equipment like radar, the navigation data, the emergency escape equipment, and the oxygen equipment. One could say that providing the aircraft with greater freedom resulted in operationally restricting the pilot, but little thought has been devoted to this hidden liability. Rather, emphasis has been laid upon the competition for enough of the cockpit space

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to cram in all the equipment that each special interest group desired. In order better to resolve this competition, miniaturization of components permitted more, although not necessarily better, units to be installed.

So much for the general mass of cockpit clutter and how, like Topsy, "it growed." Closer examination of instrument components and their development reveals two more important facts. The first most obvious one is that, when the aircraft operating limits were extended, the same old instruments were modified either by reducing the size of dial intervals to get more range on the same size dial face, adding additional pointers, or improving the basic engineering design to provide greater sensitivity and reliability. The second general conclusion is that only now when the pilot has just about reached an overload saturation is there beginning to appear genuine concern for the human factors in instrument design.

What we have today, then, as the result of bits-and-pieces development—and I feel sure most of us are unhappy about it—is a marvelously engineered vehicle with magnificent potential but possessed of a control space for the human operator which is poorly conceived, badly organized, and not well suited to the technical needs of a human operator. What this spells in terms of today's high-performance aircraft is nothing compared with tomorrow's aircraft or the day after tomorrow's space vehicles.

I propose not to dwell upon the more melancholy note I have been sounding but rather to direct your attention to the more hopeful possibilities of an integrated plan of development based upon objective analysis. This concept is not new and untried as some of you may know, for our program of instrument development at the Special Devices Center has in the past been guided by a less comprehensive but similar concept. The essential feature in the development of the concept, however, is that it was not formulated by instrumentation specialists but rather by those whom we have chosen to designate as generalists—psychologists, engineers, aviators, flight surgeons, and others able to take a broad overview of the whole flight problem unfettered by the disciplinary restrictions of the specialty groups.

We took as our primary hypothesis—subject either to later validation or invalidation—that conventional, military aircraft instrumentation provided: (1) more information mass than necessary, (2) raw information requiring complex pilot computation before it was meaningful, and (3) information displays that violated or failed to match normal patterns of comprehension.

Williams* of the University of Illinois provided us with an elementary classification system for information to be displayed, the fundamental simplicity of which has assured its continued usefulness. Williams declared that the pilot needed information about the earth, the air, his own aircraft, and other aircraft.

Flight, according to him, was composed of main and sub goals, each requiring instrumentation of a functionally different sort but providing information in one or more of the four areas above. The kinds of information displays would be either: (1) qualitative—e.g., white to red line operating range, (2) quantitative—e.g., cylinder head temperature, or (3) go-no-go, failure indicators.

In terms of the action required by the human operator, this information should be such that it tells him which control to move, when to move it, in which direction, how much, and for how long.

In addition to the classifications I have mentioned, one more type of distinction can be made between information displays on the basis of whether they are symbolic or pictorial. Obviously it is most probable that this latter separation would be in terms of qualitative information.

Concurrently with the work undertaken by Williams, the Special Devices Center commenced a program of instrument development which deliberately discarded the conventional instrumentation theories and accepted practices.

Arm chair analysis, using some of the guide lines described above, pointed to the wisdom of first considering the instrument flight training problem and what could be done about it. It appeared that the reason it required just about the same amount of time to train nonflight personnel as it did flight personnel was because each group was learning a new task; in other words, there was no carry-over of proficiency from contact flight to instrument flight, and what had been learned in the first situation was of little or no benefit in the second. The reason for this was logically concluded to be that the needle, ball, air speed, or the altitude indicator, rate of climb indicator, and directional gyro presented information in such form as to reflect no parallelism in previous experience. It followed no already known pattern of comprehension and required learning a new and entirely artificial coding system.

It was properly reasoned that an instrument that provided a display more nearly like the contact flight situation would afford a higher carry-over from contact to instrument flight training, and, furthermore, in operational use, would be a more meaningful and less fatiguing display than the several symbolic conventional instruments.

The instrument emerging from this background, the so-called Hoover horizon, is known to some of you and has been presented in some detail before this group; so I will describe it in general terms only.

Briefly it consisted of a small airplane mounted in a plastic sphere on which was painted a contact type of panorama including sky, clouds, horizon, and the earth surface as one would see it looking through the windscreen. Also included in the display around the lower part of the sphere and seen through the sphere was the familiar directional gyro scale.

* Williams, A. C., *Preliminary Analysis of Information Required by Pilots for Instrument Flight*, Technical Report SDC 71-16-1, April, 1949.

Two types of instruments were built, one in which the horizon remained fixed with reference to the aircraft structure and in which the small contained aircraft moved as the actual aircraft would appear to move if seen from another plane, and one in which the relationships were reversed.

Here then was one instrument that displayed all the information previously requiring altimeter, altitude indicator (with symbolic information), directional gyro, and needle and ball, and displayed it in a fashion that was familiar at a glance even to inexperienced people.

In another development, also familiar to some of you, we turned our attention to engine instruments because here we felt was an area of unnecessary pilot overload. All information in this category is normally displayed in precise numerical form on multiple instruments that have to be read, interpolated, judged, and compared with standards that the operator has to learn in order simply to establish that the power plants are operating properly. Seldom, we felt, does the pilot need to know the precise numerical value of an engine instrument reading; he needs such information only when failures are beginning, and he must estimate the magnitude of the impending emergency or the time available before total failure will occur.

Here was one of the most flagrant examples of supplying more information than required, as is nearly always true when quantitative data are used for qualitative purposes. Since ninety-nine and x-tenths per cent of the operating time the pilot task is simply check-reading to determine that conditions are within certain specified ranges, such quantitative information unprofitably and gratuitously complicates the pilot task, produces unnecessary fatigue, and results in reduced efficiency.

From these considerations evolved the principle of straight in-line arrangement of multiple instrument indexes when engine operating conditions were satisfactory. Breaks in the continuity of the line quickly and forcefully interrupted the quick scan of the pilot and led to faster recognition of impending malfunctions. Additional provision for getting quantitative information when needed put the display system into proper relationship with the task requirements—namely, supplying qualitative information for the greatest part of the time and quantitative information on demand when the occasion required. It was, in other words, supplying the kind of information in the proper amount and in the form most readily usable.

Frankly, in this early beginning of our new approach to the instrument problems of modern aircraft we thought all requirements could be met with this philosophy. Since then, however, enough information has come out of test flights in experimental aircraft and from other sources for us to believe instruments no longer can wisely be considered by themselves. While we used to think it only necessary to design instruments for man's understanding, we now know it is more important to design them in terms of what man does or is required to do. Essentially then it means instrument development must be put into proper relationship to the *total* flight problem and not to just a part of it, since the human pilot, in a sense, closes the loop in a feedback control circuit that determines the nature of the flight.

We feel that general recognition should be accorded to the importance of integrating the development of instruments with all other developments in air frame, power plant, mission, etc. What this kind of integration requires will be evident as I describe the elements of a plan for coordinated development—a plan I sincerely hope will be adopted to assure that all essential elements are given their proportionally proper emphasis in making aircraft more effective weapons.

There are two types of air-borne weapons, manned and unmanned, each requiring, however, the responsibility and supervision of a human operator. What distinguishes them from each other is the fact that in one case the operator accompanies the weapon, but, in the other, he remains at some remote control point. If he accompanies and rides in the weapon, the operator is a pilot and must have necessary "condition" information instantly available. The kind of information he needs can be classified as supporting either continuous or discontinuous controls, and the display of these two types of information should be quite different. What is important to remember, however, is that information is required solely for the purpose of making control possible, whether or not it is continuous. If it is more or less than required or in a form that fails to reflect the control function, it is inadequate and unsuited to the operator.

An objective appraisal of the instrumentation problem leads directly to the question of control, the first element of my integrated plan. There are three types of control, as we know, each of which creates special instrument problems—the first being automatic machine control (the autopilot, for example), the second being human control, and the third a combination of the first two. Common to all of them is the characteristic of closed-loop circuitry and hence feedback. Broadly speaking, in the case of a biological element closing the control loop, the feedback of most importance is that provided by the instrument display. Certainly it is that part of the feedback picture about which most can be done from an engineering angle.

It is not my intent, however, to minimize the importance of other sensory elements of feedback such as stick feel, "G", etc., but these are not pertinent to the subject of instrumentation.

In determining the sort of instrumentation required for a particular control task or series of tasks, the combined opinion of control experts and human engineers must be sought to select instrument displays based upon either simple displacements, velocities, accelerations, or rates of change of acceleration. Their answers on the one hand will be based upon knowledge of the stability characteristics of a control system and, on the other hand, upon predictions of, or research into, the most meaningful display of machine informa-

tion. From them can also be expected descriptions of the amount of information required and the sequence in which it will be used. Answers of this sort should serve as important fixes in developing instrumentation for the aircraft of tomorrow.

I hope you will note that I have used the term "instrumentation" instead of "instruments," for I hope thus to imply that an instrument *system* is what our goal should be rather than new instruments one by one.

With a clear recognition of the nondissociable relationship between instrumentation and controls no matter where they exist, I would draw your attention to five more elements in the integrated plan to handle separate functional areas in instrumentation development. These areas have different purposes to serve one from another and hence progress through individual modalities; from none of which, however, can we eliminate the basic objective of creating the information display to reflect what the operator must know in order to fulfill a functional requirement.

Of the five elements—in addition to, and including some consideration of the control requirement—the first one I offer is one not usually considered in a purely "instrument" situation but one which, because it is an information display, probably should be considered instrumentation of a sort. I refer to those dials or scopes that serve as extenders of the pilot's sensory abilities, primarily visual and auditory.

Even as years back Naval aircraft were known as the "eyes and ears of the Fleet," radar has come to be the eyes and ears of individual aircraft permitting man-machine effectiveness when aircraft performance would long ago have exceeded the unaided limit of a pilot's sensorium. With aircraft flying even higher and faster, more and more requirements will develop for even further extending the limits of human sensory abilities, and information displays for these extended data will have to be considerably retailored. This will be a demand placed upon display experts—the instrumentation engineers.

The second element in the whole molecule of instrumentation relates to information displays that tie internal aircraft components into systems. Examples of this functional area can be found in fire-warning displays, fuel distribution status, overall engine performance and even communication systems, perhaps, if one were to stretch a point. Here I think I could justify also including those displays that provide navigation information or describe where the aircraft is in space, for this is a piece of information involving the total aircraft and its mass of component displays.

Closely allied to internal systems is the class of displays providing information tied to systems outside the aircraft. Traffic control, radio aids to navigation such as airway marking, V.O.R.-D.M.E., I.L.S., and G.C.A., and the special military requirement for ground controlled intercept, using perhaps visual instead of auditory displays, illustrate the third element by example.

The fourth element assigns a separate category to that portion of the instrumentation which is seldom called into operation but, when needed, must be of such overriding and commanding nature as to get instant recognition. Least used but most depended upon is instrumentation that warns of threatened emergencies or aircraft failure, but, for some elusive reason, it is usually low on the priority scale and afforded but a fraction of the design consideration it should have. Examples of this functional class of instruments are practically unlimited in number and do not require description. As I am sure each of you can testify, many more proposals for this sort of instrumentation are being made continuously than can possibly or reasonably be included in the display system. After almost every crash, as a matter of fact, there is some new emergency warning indicator someone thinks should be added to the standard equipment, but such proposals rarely are adjusted to the total display system.

Finally, I come to the fifth element that serves as a vital determinant of the kind and amount of instrumentation required in any given situation—instrumentation styled in terms of the flight mission. Here the balance between the five preceding elements will be struck, depending, for example, upon whether the aircraft is civilian or military; fighter, bomber, or interceptor; day or night; all-weather or fair weather; reciprocating engine, jet, or rocket; high-altitude supersonic, or not; and a host of additional descriptions. The information displays needed in the special instrumentation determined by the mission will at least be functionally described by the operational objectives of the aircraft and its expected performance. Relative cohesion and balance between the several areas of instrumentation will be assured if their emphasis is measured in terms of total aircraft mission.

To recapitulate the six elements I like to consider jointly as the determinants of integrated instrumentation, then, they are in terms of: (1) control requirements, (2) sensory extensions, (3) internal systems, (4) external systems, (5) emergencies, and (6) flight mission.

It is of little value to establish a formal system for the considered approach to a problem such as this if its applicability and utility cannot be readily illustrated. That this organization of the problem has some merit I hope now to demonstrate by example.

To return briefly to the instrument program of the Special Devices Center I have already mentioned, you can see how we thought our approach was destined to become the only rational one; certainly it provided new and revolutionary answers to some of the instrumentation problems. The defects in our system of approach, however, chiefly lay in the concept that instrumentation was an end in itself; it dissociated the information display from the corresponding control or at least assumed that a change in one did not seriously affect the other. Furthermore, it did not satisfy the requirement for balanced effort in terms of functional importance. Its importance should not be minimized, though, for it

served as an important building block in the concept I have been describing for you.

Looking forward rather than backward, let us look at problems to come in areas we have previously considered more or less separate from each other. These previously separate areas are new instrument development, new aircraft (by types or missions), and new systems. We should satisfy ourselves first that certain proportional distributions of emphasis among the six elements of the integrated plan I have described are in fact true. Their tentative validity should be established by some meditative balance between pilot task and aircraft mission—arm-chair analysis before the fact, as it were. Obviously, the aircraft characteristics must match as nearly as possible the requirements of particular mission assignment in terms of pilot, power plant, instruments, armament, and associated equipment. Overemphasis of any one element in the combination becomes as functionally useless as a 3-ft. nose on any biped and probably just as much of a relative burden to carry around. On the other hand, underemphasis of one of the elements would result in the functional weakness that has a biological corollary in the withered arm. Balanced development seems the best paved avenue of approach to increased aircraft effectiveness, and such balance can be assured if the six elements of the plan have been properly balanced.

A further merit of this plan could be realized if it were used to point up and emphasize areas in which instrumentation engineers needed to apply greater research effort or develop more cognitive skill. Such areas might be those of cathode ray pictorial presentation, toward which radar development may be moving, or those associated with quality feedback in control systems, to mention only two possibilities. Constant survey and resurvey of the six critical elements of the integrated plan as applied to any of the new instrumentation requirements would surely bring us to a clearer understanding of our weaknesses as well as our strength. Research directed at the weaknesses would have more promising yield than random probings of the unknown.

Perhaps even more important than these long-range and somewhat remote benefits is the assurance that right now when new instrumentation is planned for a new aircraft there will not be a greater amount of display in any one of the elemental areas than is actually needed and, correspondingly, that there will be enough display in areas requiring it.

This, I know, has had the sound of vague generality, but in reality close scrutiny shows that it is specific and pertinent to every-day instrumentation problems and that it offers a high probability of earlier practical results. To indicate the theoretical content and the applicability of this integrating plan, in brief, I have: (1) examined the causes of cockpit clutter and instrument overload on the pilot; (2) proposed that an integrating plan of instrumentation development will offer earlier solutions to the problems of today's high-speed aircraft; (3) described an integrating classification system based upon consideration of human factors to be used in assessing the relative importance of six elemental areas; (4) indicated how it could rationally and fairly objectively predetermine instrumentation requirements for new aircraft; and (5) suggested that it might provide continuous assay of instrumentation research in terms of areas requiring more or less effort.

In conclusion I would say only that we have come to the point finally where integration offers us the only avenue to more meaningful instrumentation within the ever narrowing envelope of cockpit dimensions, weight allowance, and man's already overtaxed physical and psychological resources. If we fail to meet man's requirements in today's aircraft, tomorrow's aircraft may turn out to be unmanned missiles.

AUTHOR'S NOTE: For discussion of the control problem in relation to instruments see paper delivered before American Institute of Electrical Engineers, December 7, 1951: *The Human in Closed Loop Control Circuits*, by L. S. Beals.

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The All-Weather Program As Affected by Design of Electronic Equipment*

by

BRIG. GEN. MILTON W. ARNOLD, USAF (RET.)†

"RADIO—AND I SHOULD ADD the electronic complex surrounding it—is basic to our system of air navigation and traffic control today. With the resulting system of electronic aids, we want to achieve safe, efficient, and all-weather use of the available airspace, terminal runways, and airport facilities. For air power consists not only of aircraft but of its maximum all-weather utilization. Potential aid to the military is not alone so many planes but how they are used.

"In this connection, I have wanted for some time to get a load off my chest, and, though I may be mixing a metaphor, I welcome this opportunity to do so.

"Recently I read in an aeronautical magazine that the Super Constellation carries more than 1,000 lbs. of electronic equipment for air navigation and traffic control alone. What's more, this complement of equipment does not include the new components required in the transition period to the Common System which will add distance measuring equipment (D.M.E.), the radar safety beacon, and the air traffic control signaling system to the existing impediments. Nor does it include equipment such as air-borne radar and terrain warning indicators that are being proposed by various groups for installation in our aircraft.

"It seems to me that this is a serious trend. It is high time that we stopped trying to solve our air traffic control problems by addition. To date, there have been few, if any, instances where air-borne electronic equipment or systems have been obsoleted. We have for the past 20 years solved most of our problems by addition. As I say, having taken the bull by the tail and faced the issue, I want to get the issue off my chest.

"Mind you, I am not complaining about the amount of equipment as such. Four-engined aircraft are able to accommodate the numerous electronic aids currently required and those added during the transition period. But the four-engined aircraft are only part of the picture. What is hazardous and of great concern to all of us close to the problem is that the smaller aircraft cannot safely carry the numerous equipments to which the traffic control system has been geared. In other words, the solution of the problem of air navigation and traffic control by the principle of addition does not give an acceptable standard of traffic control to smaller aircraft.

"Until recently, our traffic control tools, such as voice communication, point-to-point wire circuits, voice radio air-ground circuits, teleprinters, and posting board slips on which the air traffic control makes penciled notes, have been of highly flexible nature. Specific air traffic controllers could make whatever changes or innovations in the use of these equipments deemed necessary to meet their individual desires or to meet the special needs of the area in which air traffic was being controlled.

"However, at the present time, we are faced with the problem of an ever-increasing number of voice radio circuits and voice telephone circuits. An ever-increasing number of persons are talking over these circuits so that coordination between them is becoming more and more difficult, to the extent where air traffic control may soon be below an acceptable safety level.

"In other words, we are at the point in aviation where it is essential to introduce mechanical and electrical systems capable of providing coordination between air traffic controllers and the essential interlock features in order to prevent human error in the insertion of information into the overall system. We can no longer improvise but must understand our specific traffic control philosophy and procedures and tailor our system to meet the *basic requirements*.

* Excerpts from the Electronics Day Luncheon address, I.A.S. Annual Meeting, New York, January 30, 1952.

† Vice-President—Operations & Engineering, Air Transport Association of America.

"In my opinion, this is the heart of the issue—the operational philosophy that should guide us all in our approach to the air traffic problem today. If we solve the basic overall problem, the details will take care of themselves. That is to say, their relationship to the basic problem will become clear, and they will not become ends in themselves. By working in terms of the problem—and the problem must be clearly set forth and thoroughly understood—designers of electronic equipment would not be tempted to solve the details or to offer solutions that are at best tangential to the basic traffic problem. Such practice would, by its very nature, prevent us from trying to solve our operational problems by addition. This is the vision that designers must develop if safe, all-weather utilization of aircraft is to be obtained. There is reason to hope that all really basic requirements can be met, but, with only a few arbitrary additional requirements, the problem could be rendered forbidingly difficult. In R.T.C.A., SC-31, principles were set forth which included operational and equipment factors under the heading Integration and Evolutionary Implementation. In this appeal for an efficient air navigation and traffic control system, equipment flexibility was stressed.

"To date, these principles have not been faced in the actual systems planning effort. Instead of being highly flexible in nature, new equipments, such as D.M.E., Radar Safety Beacon, and the A.T.C. Signaling System, are inflexible, having somewhat the characteristics of a strait jacket. It is true that at the present time these electronic aids appear to be the best approach to the solution of the problems for which they were designed.

"However, if we continue to develop an additional equipment for each new operational requirement, the air lines will be faced with a situation where the radio compartment and the food canteen meet in the center of the passenger cabin, and they will be out of business.

"Hence, it is mandatory that we renew our efforts to understand our operational problems, clearly stating them for both the designers of aircraft and the designers of electronic aids, so that the individual air-borne equipments that result will have a high degree of flexibility and operational adaptability. In this way, the basic operating requirements can be met with the minimum number of electronic components. As already stated, a safe air traffic control system cannot be based solely upon what large transport aircraft can carry. In fact, it would be more realistic to plan equipments for smaller aircraft which at the same time would be suitable for the larger planes.

"To reiterate the philosophy already stated, it is now time that we brought air traffic control planning out of the 'blue sky' stage and out of the stage of agreement by addition. Each year there is an increased range of aircraft performance, resulting in a new range of electronic problems pressed on the systems designer. And each year the design of aircraft moves further and further away from the achievements made in improving the air navigation and traffic control system. As the speed range and altitude range of aircraft increases, the problems of maintaining safe separation of aircraft and efficient flow of aircraft in air traffic control increases. Hence, it is more than ever imperative to restate the operational problems that are causing the electronic designs to become so complex that they are either too costly and unrealistic or they take too long to develop.

"With a practical approach to aircraft design and to the basic improvements needed in the current system of air traffic control, together with such modification of procedures and practices as may be required for a straightforward, logical development of each, a reconciliation can be made between the designers of aircraft and the designers of electronic equipment for air traffic control.

"Such a reconciliation should result in a system that performs the fundamental job of maintaining safe, efficient, and all-weather operation of existing aircraft in the available airspace while remaining sufficiently flexible and adaptable to accommodate additional aircraft as they move into the overall traffic pattern. And the resulting system would benefit both civil and military aircraft by increasing the effective air power represented by any given number of aircraft."

Review of Current Electronic Literature

For further information on current articles pertaining to electronics in aviation, refer to the Aeronautical Reviews Section of this magazine (pages 137–146, this issue).

Storm and Clear Air Turbulence

An Analysis of the Problem and a Search for Solution

A. F. MEREWETHER* and F. C. WHITE†

American Airlines, Inc., and Air Transport Association

Introduction

In our day there still are many people who have not had their first trip in an aircraft. A death in the family or a hurried business trip may be necessary to bring about that "first ride." It is undoubtedly true that many of these people avoid taking that first trip in an aircraft because they have been told that the flight, inevitably, will subject them to a rougher ride than that usually associated with a trip over a plowed field on the tail gate of a wagon. To dispel this thought and to orient the problem of turbulence in flight as to quantity and degree, let us review first what the record has to show.

Amount of Turbulence Encountered in Flight

The National Advisory Committee for Aeronautics, as a result of years of research and data accumulation, is an excellent source of information on turbulence encountered in flight. Fig. 1, plotted from information obtained from N.A.C.A., gives the distances that may be flown in various types of weather before certain maximum gust velocities are encountered. To determine what maximum gust velocity would be encountered, on the average, in a routine flight of 1,000 miles, we must estimate what proportion of the flight will be flown in the various types of clouds. If we estimate that 1 per cent of the trip will be flown in thunderstorms, we establish that at least one gust of 17 ft. per sec. will be encountered. If we can avoid all thunderstorms and cumulus clouds through forecasting or the use of airborne radar, the 1,000-mile flight would not encounter a single gust over 13 ft. per sec.

Effective gust velocity (*Ue*) (ordinate of Fig. 1) has been extensively used by N.A.C.A. and others as the most convenient method of comparing the gust loads imposed on various aircraft structures. *Ue* data taken on one airplane can be used to approximate closely the gust loads for other airplanes even though their flight speed, size, or gross weight vary considerably from that of the aircraft used for data collection.

In terms of modern transport aircraft, a gust velocity of approximately 17 ft. per sec. is required at cruising speed to produce a load of two g's, twice the gravitational pull of the earth. In laymen's language, a two-*g* load is just sufficient to lift you against your seat belt.

Fig. 2 shows us one of the advantages of modern, pressurized aircraft. The older, nonpressurized aircraft cruising at less than 8,000 ft., on the average, would encounter a maximum true gust velocity of 20 to 25 ft. per sec. per 1,000 miles of flight. A modern, pressurized transport aircraft, cruising at 20,000 ft. would encounter a maximum true gust velocity of 17 ft. per sec. in the same 1,000-mile flight.

Since the figures are given in terms of "true gust velocity," the difference in maximum *effective* gust velocity, or load on the airplane, would be greater than the figures plotted because "true gust velocity" takes into account the variation in air density with change of altitude.

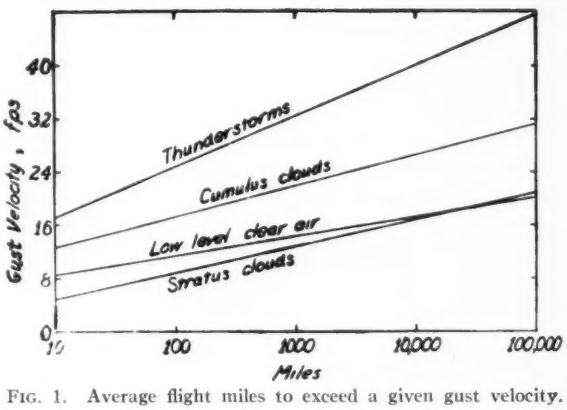

Fig. 1. Average flight miles to exceed a given gust velocity.

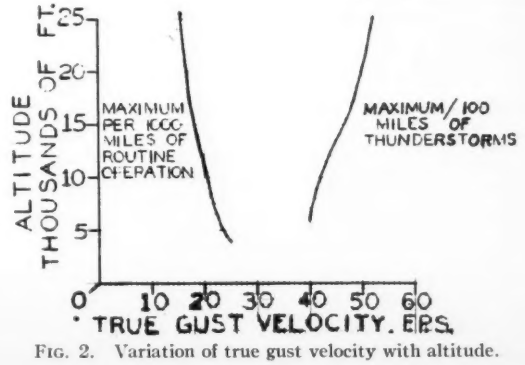

Fig. 2. Variation of true gust velocity with altitude.

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Fig. 2 re-emphasizes the importance of avoiding thunderstorms, regardless of the flight altitude.

Forecasting Turbulence in or Near Clouds

Turbulence may be caused by instability, shear, or orographic effect. Instability is usually considered the primary factor so that forecasting turbulence is, in essence, a matter of estimating the degree of instability to be expected with due consideration to moisture distribution. There is no foolproof method of arriving at these values, but study of radiosonde ascents, winds aloft, and constant pressure charts gives a fair picture of the recent past state of the atmosphere. By projection from this, a fair estimate may be made of conditions to be expected in the succeeding period, with the severity of the turbulence directly related to the magnitude of the lapse rate.

The severity of the turbulence is also a function of the depth of the unstable layer as well as the degree of instability. Areas of severest turbulence, as is well known, are associated with thunderstorms since in these storms the air inside the rising cloud is considerably warmer than the surrounding air, and this condition extends through a layer many thousands of feet thick. The magnitude of the temperature difference inside and outside the cloud, as determined on a plotted raob ascent, is a measure of the severity of the turbulence to be expected.

Severity of the turbulence (the number of *g*'s to which the passenger is subjected) is also a function of the speed of the aircraft. It is standard procedure to slow down when encountering turbulence in order to lessen the bumps and jolts.

Light to moderate turbulence frequently occurs on summer afternoons in the lowest 5,000–6,000 ft. of the atmosphere due to the sun's heating at the surface which sets up an unstable layer through this depth. In desert areas, the turbulence may extend considerably higher.

Another type of meteorological situation that will cause turbulence in the lower 6,000–7,000 ft. of the atmosphere is one in which high winds occur throughout the depth of the layer from the ground up. This causes complete mixing throughout the layer, resulting in an unstable condition with a nearly adiabatic lapse rate. This lapse rate combined with considerable wind shear results in moderate and occasionally severe turbulence. Fair success may be expected in forecasting turbulence because of insolation or high winds.

Forecasting of turbulence associated with fronts and thunderstorms is a matter of experience and the use of a number of different tools. The first problem is to forecast whether thunderstorms are going to exist at all. This involves an estimate of the vertical temperature and moisture structure over the area, and whether the necessary lifting is going to be available to trigger off the release of energy for the development of the thunderstorms. Frequently, the forecast of thunderstorm activity is based on a knowledge concerning thunderstorms already in existence. Many aircraft fly the airways of this country. Good communication with these aircraft and among the aircraft themselves provides rapid interchange of current information on weather being encountered in flight.

It is not always easy to forecast the initial onset of a squall line, but, once established, some idea of its future movement and intensity may be gained from its previous performance. Thus, the speed of movement will help to locate the area of thunderstorms several hours in the future. Intensity and duration of heavy rainfall, occurrence of hail, maximum surface winds, magnitude of the pressure fall and rise during the storm's passage, and pilots' reports all give a clue to the severity of the storm then occurring and what might be expected downwind several hours later.

The intensity of thunderstorm activity is also often directly related to the severity of the cold front—that is, the magnitude of the temperature contrast through the front and the sharpness of the wind shift. It has also been shown that the severest thunderstorms—those producing much hail and possibly tornadoes—seem to occur in air saturated throughout the lowest 5,000 to 10,000 ft. but extremely dry above that. If the air is saturated through the first 10,000 to 20,000 ft. and is dry above, the thunderstorms are of only moderate severity, and the amount of hail produced is considerably less. If the atmosphere is moist throughout the surface layer to levels above 20,000 ft., then thunderstorms are still less violent with little or no hail.

Historical sequence is also an important forecasting aid. Squall lines preceding cold fronts frequently develop and intensify in the afternoon and die out late at night and follow the same pattern the next day and the day after. Nocturnal thunderstorms frequently occur night after night as they did this summer in the great flood areas. Thus, what happened one night would be used, assuming no change in air mass, as an indication of what might be expected the following night. Even climatology has its contributions; for example, the Colorado Rockies in the spring and the Florida peninsula in the summer are sure to produce thunderstorms day after day. Thus, it is apparent that forecasting turbulence is neither a simple nor an exact procedure.

Detection and Display of Thunderstorms

The pilot, aided by the meteorologist, can avoid the majority of all thunderstorms that lie along his flight path. It has been demonstrated that radar will detect and display *all* active thunderstorms—those that have precipitation. For example, the "Thunderstorm Project" of the Air Force, Navy, N.A.C.A., and Weather Bureau demonstrated that radar could be used operationally to detect and depict that part of a cloud which contained precipitation. Under contract to the Navy, American Airlines demonstrated not only that air-borne radar could be used to detect and display thunder-

storms, but that a special type of radar presentation, which displayed change in rainfall rate, might eventually be a suitable method of displaying the most turbulent areas of thunderstorms. The radar used by American Airlines was a 15-kw. peak power, 3-cm. equipment. The PPI (radar) display was mounted in the cockpit of the aircraft to permit the pilot to use the radar information firsthand.

Fig. 3 shows a PPI installation in the cockpit of a Douglas DC-6 aircraft. It is hoped that new developments in bright PPI tube displays eventually will eliminate the most serious shortcoming of air-borne radar—the limited brilliance of the PPI display. This shortcoming makes it necessary to install a truncated cone hood over the end of the PPI display to shield off the ambient light in the cockpit. This expedient still does not compensate completely for the lack of PPI brilliance which makes it difficult, and occasionally impossible, to use the PPI display during daylight hours.

The radar display developed by American Airlines to display the change in rainfall rate included circuitry that would erase the display from the PPI scope when the echo from a thunderstorm exceeded a preset value.

Fig. 4 shows the usual thunderstorm display. This photograph was taken by American Airlines during an actual thunderstorm probing flight. Fig. 5 (taken 1 sec. after Fig. 4) shows the same thunderstorm with the special circuitry in operation. A two-tone display results. Assuming no distortion of the display due to precipitation attenuation, the dark portions of the thunderstorm echo represent the heavy rain areas. Two contours are created by this display—the threshold contour, around the periphery of the echo, and the contour surrounding the erased portion of the echo. These contours are isoecho areas, but are not necessarily isohyets since there is considerable attenuation of the 3-cm. radar signal from the precipitation itself. To reduce to a constant, insignificant value the effect of attenuation, American Airlines analyzed its radar data at a constant range of one-half mile.

Fig. 6 from American Airlines' Final Report to the Navy, which was based on limited data (598 miles of flying within thunderstorms or within 5 miles of thunderstorms), shows us that as the spacing between the two isoecho contours decreases, the number of gusts increases. Thus, it would appear that turbulence in thunderstorms is associated with the change in rainfall rate.

The reduction of distortion in PPI rainfall rate contour displays, as a result of precipitation, requires only that the radar be operated on a wave length longer than 3 cm.; a value in the neighborhood of 6 or 7 cm. has been suggested as appropriate.

Forecasting Clear Air Turbulence

Clear air turbulence in the higher levels (above 15,000 ft.) has become important mainly in connection with jet operations. Since it cannot be seen or otherwise detected in advance, it cannot be avoided. Comparatively little is known about the cause, and less is known about forecasting it. However, studies so far seem to indicate that wind shear in the vertical is the most probable cause and that thermal instability may be disregarded. In fact, generally speaking, the temperature lapse rate associated with clear air turbulence seems to be markedly stable. Since the jet stream is a region of high wind shear, this may offer some forecasting clue; but jet streams have been penetrated without incident on numerous occasions. Furthermore, we cannot forecast the position of the jet itself with accuracy. In ad-

Fig. 3.

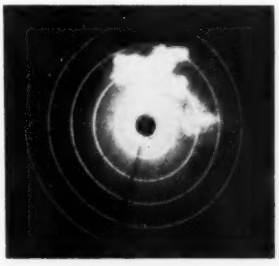
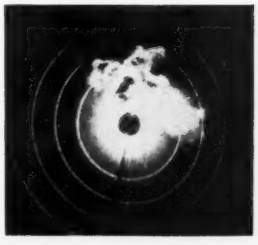


Fig. 4.



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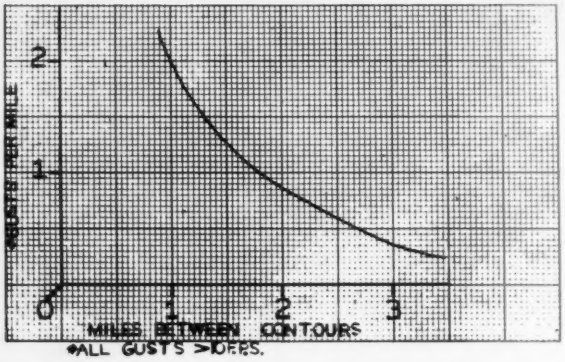

FIG. 6. Change in frequency of gust occurrence with isoecho contour spacing.

dition, the turbulent areas are of small vertical extent. Thus, at the moment, the outlook for forecasting clear air turbulence is not promising.

DETECTING CLEAR AIR TURBULENCE

At present, we do not know how to detect clear air turbulence before we encounter it. However, a first approach is now being attempted by the Weather Bureau and N.A.C.A. in a joint project through the use of gustsond. Basically, this is an instrument with a weight suspended on the end of a vibrating arm, the magnitude of the fluctuations of the arm depending on the severity of the turbulence. By means of radio, these fluctuations are transmitted to a receiver on the ground which transposes the signals into a smooth or wavy line according to the turbulence encountered. The instrument is borne aloft by balloon to a predetermined altitude where the balloon bursts and drops the instrument by parachute. It descends at a steady rate and transmits only on the way down. Since the release of the instrument is made at the time of radiosonde ascents, it is frequently possible to determine whether the turbulence occurred in clear or cloudy air. Currently, daily gustsond observations are being made at Caribou, Me; Washington, D.C.; Miami, Fla.; and Grand Junction, Colo.

SUMMARY

The amount of turbulence normally encountered in flight is not of serious consequence. It has deterred some people from accepting air transportation and therefore deserves our serious attention.

The forecasting of turbulence in clouds is far from an exact science and requires the development of new techniques and aids, electronic and otherwise.

The detection and avoidance of the major source of turbulence in flight, the thunderstorm, is within our grasp but requires improvement in the brilliance of the PPI display and a radar operating on 5- to 6-cm. wave length.

The detection and forecasting of high-altitude, clear air turbulence is a new science about which we know little.

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Heat-Transfer Design Problems in Aircraft Electronic Equipment

LEONHARD KATZ*

Raytheon Manufacturing Company

WITH THE ADVENT OF HIGH-VELOCITY AIRPLANES traveling at higher altitudes, several new problems have arisen which materially affect the design and construction of electronic equipment in the aircraft. These problems have become so acute that they are forcing a complete redesign of most of the electronic equipment and a change in the thinking as to the method of installing electronic equipment in aircraft.

The special problems pertaining to electronic equipment in modern aircraft for operation between sea level and high altitudes can be summarized as follows.

(*a*) *Increased Heat Dissipation.*—More and more functions in the aircraft are taken over by the electronic equipment; consequently, the total amount of electronic equipment in an aircraft has considerably increased. As a result the total heat generated has been tremendously increased. However, not only has the quantity of electronic equipment in an aircraft been increased, but the equipments have been designed to perform more complicated functions requiring a greater power output, which has again increased the total heat generated.

(*b*) *Higher Temperatures of Operation.*—When electronic equipment was first installed in aircraft, the problem of heat dissipation and the resulting temperature rise was not too serious, since the equipment was large and the amount of heat generated was small. With more modern equipment and a continuous trend toward miniaturization, the amount of heat generated is greater than before, but the amount of heat generated per unit volume has been tremendously increased. Consequently, heat removal has become one of the major problems in air-borne electronic equipment. To make the heat removal problem even worse, the following external circumstances have complicated the matter.

(1) The air at high altitudes is less dense, therewith making the heat removal a greater problem.

(2) If the velocity of the airplane is increased, skin friction and ram temperature rise cause a distinct rise in the temperature of the air and the skin of the aircraft, therewith making normal cooling methods rather difficult.

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It can be seen that the operation of electronic gear of compact design at high altitudes brings with it a number of problems that appear to be all centered around the problem of the removal of heat. It is, therefore, of interest to study the problem of heat transfer a little more in detail to determine what type of approaches can be used with success and which approaches are likely to cause trouble.

The first thing that must be kept in mind in studying heat transfer in aircraft electronic equipment is that, although the heat transfer is a serious problem, it cannot be solved at the expense of the rest of the airplane. Many times a heat-transfer problem is solved for an individual equipment, resulting in a heavier load on another equipment at a different location in the airplane. This often increases the overall weight of the plane considerably. Consequently, the heat-transfer problem must be handled as an integral problem of high-altitude aircraft design, and the criterion that will be used here for the determination of the successful solution to a heat-transfer problem will be the potential reduction in the overall size and weight of the airplane. In other words, it is intended to "weigh" the aircraft before the installation of electronic gear and "weigh" it again after the installation of the electronic gear including all its auxiliaries such as blowers, heaters, generators, cables, etc. The overall weight increase is then chargeable to the electronic gear, and any new method of heat transfer will have to stand this "weighing" test to determine its effectiveness.

In order to find some solutions to the problems of heat transfer, efforts were expended in two directions as follows: (a) the design of electronic equipment and its cooling system to permit the equipment to operate at high altitudes without failure, without regard to reduction in weight; and (b) design of electronic gear and its associated cooling system to reduce the overall weight of the airplane.

Before going into a description of the investigations undertaken to solve these problems, a brief discussion of the basic principles of the heat-transfer problems is in order at this point.

PRINCIPLES OF HEAT TRANSFER

Let us examine a simplified piece of electronic equipment consisting of a small box in which a certain amount

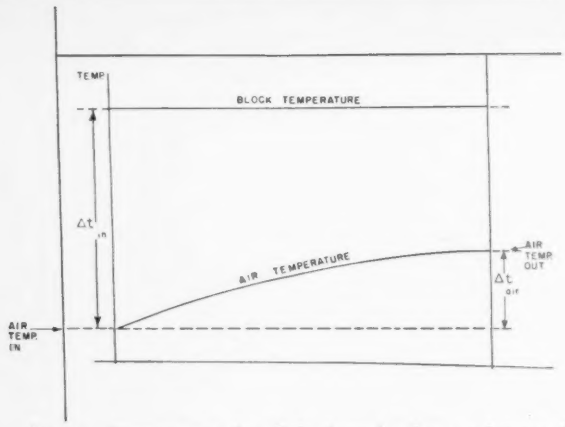

FIG. 1. Temperature rise of air through a heat exchanger of constant temperature.

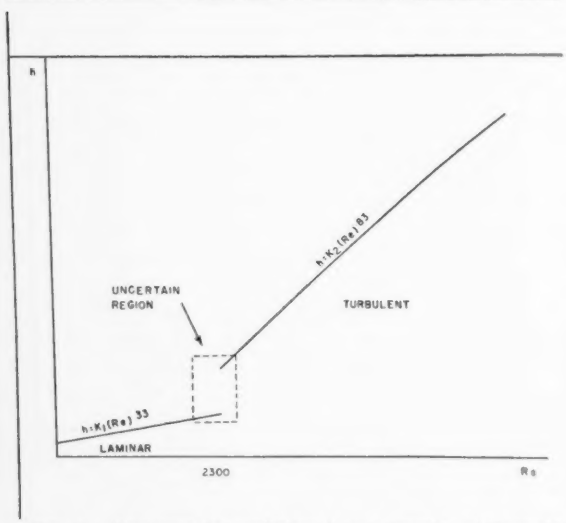

FIG. 2. Heat-transfer coefficient h as a function of Reynolds Number in laminar and turbulent flow.

of heat is generated. This heat is being continuously generated and will heat up the box containing the electronic equipment to a higher temperature. If the box is completely insulated and no heat is removed, the temperature of the box will continuously increase as a function of time until the heat generating elements inside the box are destroyed due to the high temperatures reached. If the heat is removed by various conduction paths or by radiation, the temperature of the equipment will only increase up to a point where a balance is obtained such that the heat generated is equal to the heat removed.

The generation of heat can be compared to the generation of electric current. In the generation of electric currents we are familiar with Ohms law, which states that

$$E = IR \tag{1}$$

In other words, the generation of a current through a certain resistance will produce a voltage of a certain magnitude across this resistance.

A similar law exists in the generation of heat which can be stated as follows:

$$\Delta T = QR \tag{2}$$

In other words, the heat generated, Q, through a certain resistance, R, will produce a temperature difference, ΔT, across this resistance. The generation of heat in electronic equipment is usually fixed, and, in analogy with the generation of electrical current, the problem can be compared to that of a constant current generator.

Assume we have a constant current generator producing a specific voltage across a resistance R. If we were to limit the voltage E which is to be produced, then we can do one of two things. We can either reduce the amount of current generated, or, if this is not feasible, we can reduce the resistance through which the current must flow.

In the analogous problem in heat transfer, we would like to limit the temperature rise ΔT, because a high temperature usually produces destruction of the equipment due to voltage breakdowns, changes in resistance, etc. Consequently, there are two things that we can do. We can either reduce the heat generated, or, if this is not possible, we can reduce the resistance R through which the heat must flow. All methods of reduction of the temperature difference and heat removal are essentially based on the principle of reducing the resistance to heat flow.

Resistance to Heat Transfer

In order to reduce the resistance to heat transfer, it might be well to study carefully the components that make up the overall resistance to heat transfer. These components can be described as follows:

(*a*) *Resistance in Conduction*

For conduction of heat through a solid of constant cross section, the following relation exists.

$$Q_{cd} = kA(\Delta t/x) \tag{3}$$

The resistance can be expressed by the following equation

$$R_{cd} = (x)/kA = 1/h_{cd}A \tag{4}$$

where $h_{cd} = k/x$. A is the cross-sectional area of the conductor, x is the distance along the conductor, and k is the thermal conductivity of the conductor.

(*b*) *Resistance in Radiation*

The heat transfer due to radiation can be expressed by the following equation:

$$Q = 0.173\,A\epsilon[(T_1/100)^4 - (T_2/100)^4] \tag{5}$$

It is a function of the difference of the fourth power of the temperatures involved, but the resistance can be defined as a function of the radiation heat-transfer coefficient and can be expressed as follows:

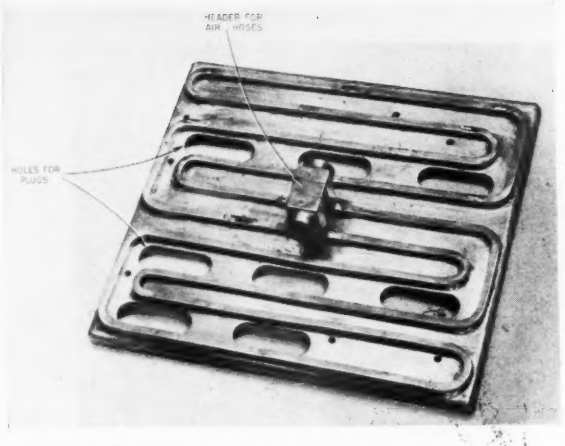

FIG. 3. First experimental turbulent air cooling plate. Designed to cool 100 watts with a maximum plate temperature rise above ambient of 30°C. and an air pressure drop of 10 lbs. per sq.in.

$$R = 1/h_r A \tag{6}$$

where

$$h_r = \frac{0.173\ \epsilon[(T_1/100)^4 - (T_2/100)^4]}{T_1 - T_2} \tag{7}$$

This heat-transfer coefficient of radiation h_r is a function of the temperature difference and the emissivity.

(c) *Resistance in Convection*

The heat transfer due to convection can be expressed by

$$Q = h_{cr} A \Delta T_m \tag{8}$$

The resistance in convection can be expressed by the following formula:

$$R = 1/h_{cr} A \tag{9}$$

where h_{cr} is the coefficient of heat transfer and A is the surface area of the equipment. This general formula for the resistance holds true for all forms of convection, either natural convection or forced convection.

It can be seen from the foregoing abbreviated discussion of resistances involved that the resistances in heat transfer all appear to have the following properties in common.

(a) The resistance is inversely proportional to the area over which the heat transfer takes place. In the case of conduction, this is the cross-sectional area, and, in the case of radiation and convection, this is the surface area.

(b) The resistance is inversely proportional to the heat-transfer coefficient. The heat-transfer coefficient in the case of conduction is k/x. In the case of radiation and convection, the coefficient is more complex in nature. The elementary examination of the resistances involved indicates that, in general, two methods of approach can be followed in the solution of a heat-transfer problem to reduce the resistance to the heat transfer: (1) the area available for heat transfer may be increased; and (2) the heat-transfer coefficient may be increased.

FIG. 4. Second experimental turbulent air cooling plate. Designed to cool 300 watts with a maximum plate temperature rise above ambient of 30°C. and an air pressure drop of 1 lb. per sq.in.

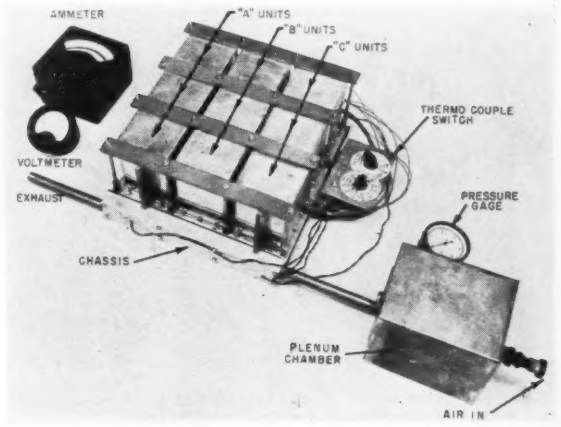

FIG. 5. Experimental setup with second plate, showing location of hermetically sealed units on plate. A and B units were 30 watts each; C units were 40 watts each. Total heat dissipation, 300 watts.

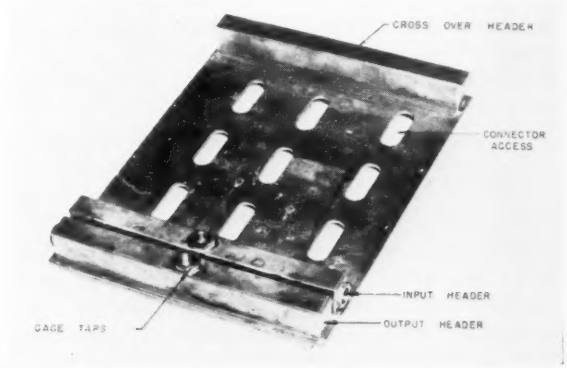

FIG. 6. Third experimental turbulent air cooling plate. Similar to second plate except made of sheet metal throughout.

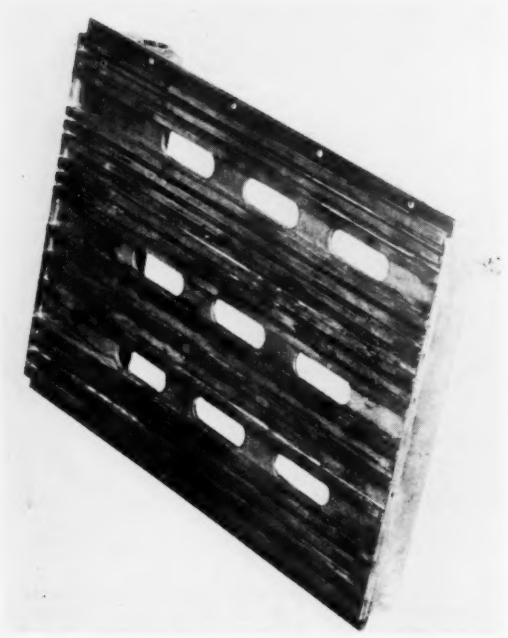

FIG. 7. Third plate. Bottom view showing location of turbulent air cooling tubes.

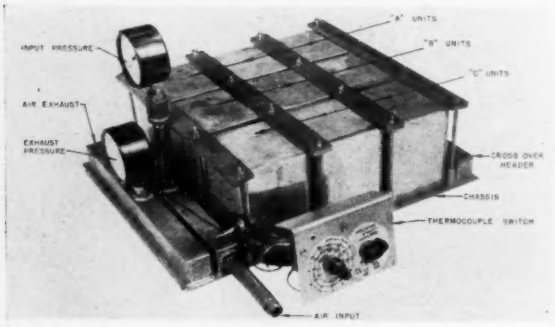

FIG. 8. Experimental setup with third plate, showing location of hermetically sealed units on plate.

SOLUTION OF THE COOLING PROBLEM

The solution of the first problem—i.e., the design of electronic equipment and its cooling system to permit the equipment to operate at high altitudes—must now be found in the reduction of the resistance between the source of heat generation and the heat sink. This reduction in resistance, however, must take into account the overall resistance.

One system that has met with considerable success and which reduces the overall resistance between the outside air (heat sink) and the electronic equipment (heat source) is the so-called turbulent air cooling system, which will be described in more detail here. The turbulent air cooling system essentially is a high efficiency cooling system in which the outside air is brought in such intimate contact with the heat source that: (a) the outside air is "loaded up" with heat to its maximum capacity and (b) a minimum temperature rise is generated in the equipment.

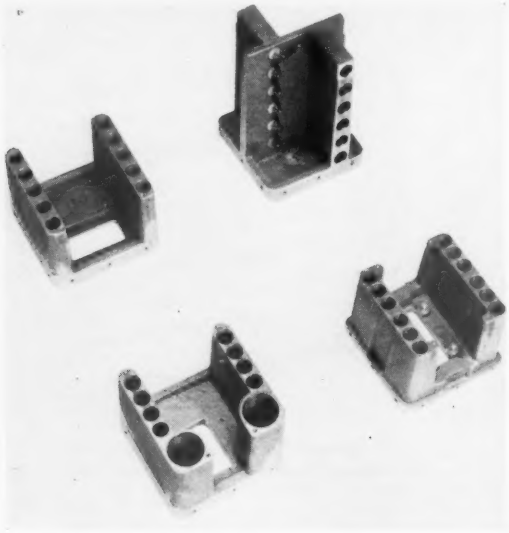

FIG. 9. Experimental castings of hermetically sealed electronic chassis for mounting on turbulent air cooling plates. Holes in the casting are for mounting of miniature and subminiature tubes.

The choice of the turbulent air system was dictated by the necessity to use the medium that is best available. In airplanes the ultimate heat sink must be air. Consequently, an air-cooling system would be most advantageous. In other vehicles, such as ships, a water-cooling system may be most advantageous. In general, the cooling system should use whatever medium is available.

Inasmuch as the medium available in an airplane is air, an effort was made to design a system that utilized air cooling. This, however, brought up some novel problems, since it is difficult to bring the outside air in intimate contact with the heat sources. For instance, in a normal electronic equipment, air is usually circulated through the equipment by means of a fan. Rather large quantities of air are circulated, and the temperature rise of the air is usually extremely small. This is caused by the fact that there is a considerable resistance, prohibiting good contact between the air and the heat source. It can, therefore, be said that the air is used rather inefficiently.

Fig. 1 shows a typical diagram of the temperature rise in an air stream going past a hot body. If the air were used to its maximum capacity, it should reach the temperature of the body when it leaves the equipment. This would ensure that the heat-carrying capacity of the air had been used to its fullest extent.

We define the efficiency or figure of merit of a heat exchanger

$$\eta = \Delta T_{\text{air}}/\Delta T_{\text{in}} \tag{10}$$

The efficiency of the heat exchange in most electronic equipments is usually extremely low and varies between 2 and 20 per cent. This low efficiency makes the system rather costly at high altitudes where air is at a premium, and, consequently, a system of higher efficiency is required. With the turbulent air tech-

niques, efficiencies usually lie in the region between 70 to 95 per cent so that a minimum of air is required. It is, therefore, desirable to investigate means by which the efficiency of heat transfer can be increased.

The heat transfer between air and a metallic surface is usually governed by the following parameter: (a) Area of transfer, (b) the temperature difference ΔT, and (c) the thickness of the stagnant layer that forms the resistance to heat transfer.

This stagnant layer can best be explained by examining the condition of heat transfer in a tube. If air is moved through a tube, the velocity distribution will be parabolic (or closely approximating this), indicating a high velocity in the center and a low velocity near the wall. If the velocity of the air in the tube is increased, a point is reached at which the flow characteristics change suddenly and instead of a streamline flow, a highly turbulent flow starts with a completely different velocity distribution than was experienced before. It has been found that the critical variable in the determination as to whether the flow is laminar or turbulent is the Reynolds Number where $Re = DV\rho/\mu$. In general, at $Re < 2{,}300$ the flow will be laminar, and at $Re > 2{,}300$ the flow will be turbulent. Under conditions of turbulent flow, the stagnant layer on the surface which forms the main resistance to heat transfer is considerably reduced, resulting in an increase in the heat-transfer coefficient. It has been shown that, in general, under conditions of laminar flow, the heat-transfer coefficient will be governed by the following equation:

$$h = \frac{k}{D} \times 1.86\,(Re)^{0.33}(Pr)^{0.33}\left(\frac{D}{L}\right)^{0.33} \qquad (11)$$

Under conditions of turbulent flow, the heat-transfer coefficient will be governed by the following equation:

$$h = 0.023(k/D)(Re)^{0.83}(Pr)^{0.44} \qquad (12)$$

If we consider a tube of a fixed length and diameter and air passing through at constant temperature, viscosity, velocity, conductivity, density, and specific heat, we can see that these equations reduce to:

$$\text{For laminar flow:} \quad h \cong K_1(Re)^{0.33} \qquad (13)$$

$$\text{For turbulent flow:} \quad h \cong K_2(Re)^{0.83} \qquad (14)$$

This shows that there is a distinct jump in the curve at the critical Re where turbulence first begins, and also that in the turbulent region the slope of the curve has been considerably increased. It is apparent that it is to great advantage to design heat-transfer apparatus to operate in the turbulent region as this obviously reduces one of the main resistances in the circuit—i.e., the resistance of the stagnant layer. Turbulence in the air for the transfer of heat from the source to the sink in electronic equipment can best be obtained by moving the outside air through tubes under such a condition that the Re is considerably in excess of 2,300. By proper design this can be successfully done and extremely high rates of heat transfer can be obtained.

Application of the Theory to Equipment

A first experimental plate for the investigation of the turbulent air cooling of electronic equipment is shown in Fig. 3. This plate was approximately 1 ft. square

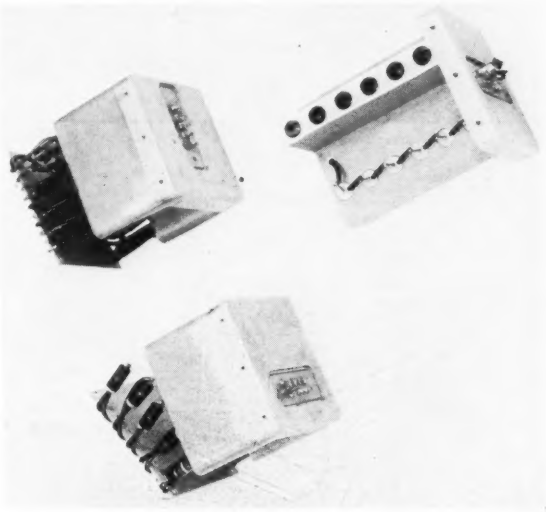

Fig. 10. Heat loading of castings with resistors for heat-transfer experiments.

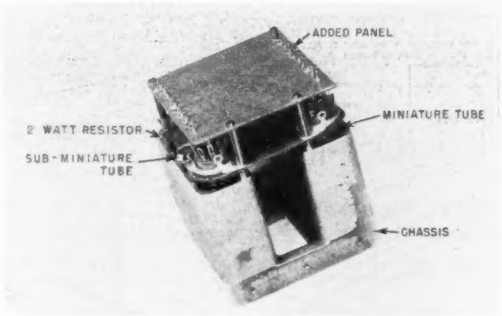

Fig. 11. Mounting of component panels and tubes in castings

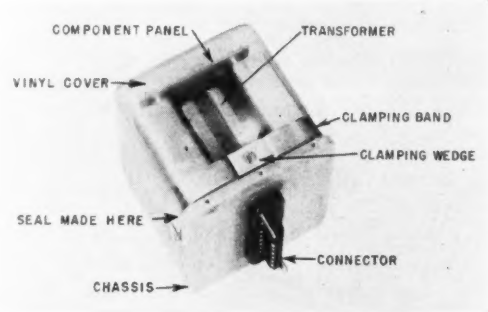

Fig. 12. Complete hermetically sealed unit with sealed connector, vinyl cover, and components. Metal can fits over the vinyl cover for protection.

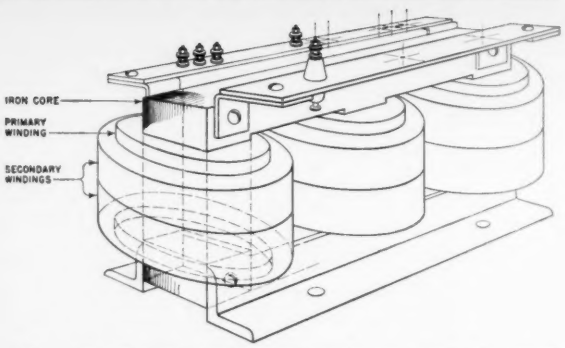

FIG. 13. Conventional plate transformer used for experiments. Rating: 1,100 volt amperes, Class A insulation. Weight, 18 lbs., volume, 202.5 cu.in.

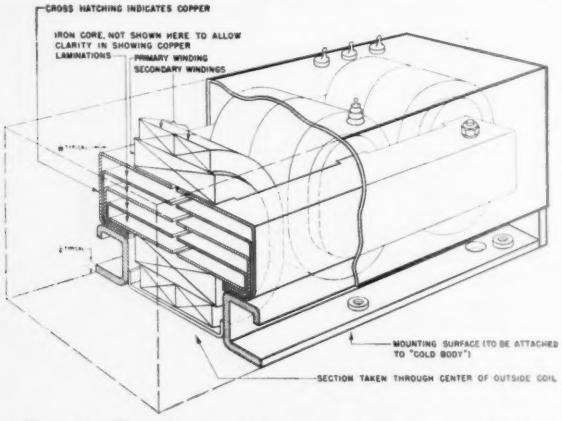
CROSS HATCHING INDICATES COPPER
IRON CORE, NOT SHOWN HERE TO ALLOW CLARITY IN SHOWING COPPER LAMINATIONS
PRIMARY WINDING
SECONDARY WINDINGS
MOUNTING SURFACE (TO BE ATTACHED TO "COLD BODY")
SECTION TAKEN THROUGH CENTER OF OUTSIDE COIL

FIG. 14. Transformer with copper paths in core for heat transfer to cooling plate.

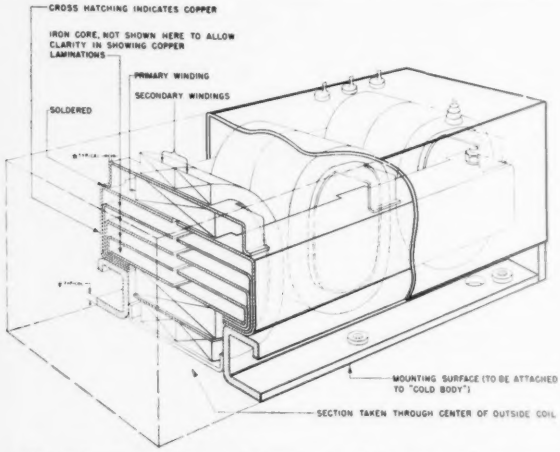
CROSS HATCHING INDICATES COPPER
IRON CORE, NOT SHOWN HERE TO ALLOW CLARITY IN SHOWING COPPER LAMINATIONS
PRIMARY WINDING
SECONDARY WINDINGS
SOLDERED
MOUNTING SURFACE (TO BE ATTACHED TO "COLD BODY")
SECTION TAKEN THROUGH CENTER OF OUTSIDE COIL

FIG. 15. Transformer with copper path in core and one wrap of copper between primary and secondary windings for heat transfer to cooling plate.

and was designed for the cooling of approximately eight hermetically sealed chassis that were to be mounted on the plate. A tube with a square cross section was soldered onto this plate and bent around so as to have considerable surface area contact with the plate. The entrance header in the middle permitted the air to flow through both tubes. This first plate

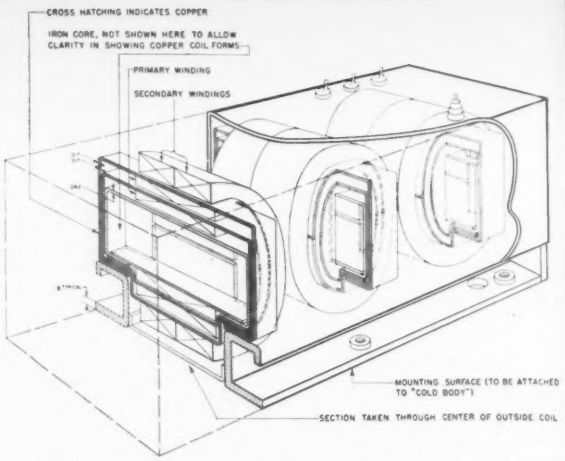
CROSS HATCHING INDICATES COPPER
IRON CORE, NOT SHOWN HERE TO ALLOW CLARITY IN SHOWING COPPER COIL FORMS
PRIMARY WINDING
SECONDARY WINDINGS
MOUNTING SURFACE (TO BE ATTACHED TO "COLD BODY")
SECTION TAKEN THROUGH CENTER OF OUTSIDE COIL

FIG. 16. Transformer with copper coil forms and with double wraps of copper in center of primary windings and between primary and secondaries of each coil for heat transfer to mounting surface.

was designed for a pressure difference of 10 lbs. per sq.in. and has an efficiency well in excess of 90 per cent.

A second plate was then designed as shown in Figs. 4 and 5. This plate consisted of a solid metal plate approximately $1/4$ in. thick into which a number of grooves had been milled. An entrance and exit header were mounted at the end, and a cover plate formed the fourth wall of the air ducts. Tests were run with this plate indicating an efficiency slightly less than the previous plate but still approximately 70 per cent. This plate was made of aluminum and had considerable weight but served as a basis for experiments with this method of cooling. It was found that the hermetically sealed chassis that were mounted on this plate had good heat transfer from the units to the plate so that the overall temperature difference between the hermetically sealed units and the outside air was extremely small. The usual design is such that with a heat dissipation of approximately 300 watts per sq.ft. the maximum temperature rise between the plate and the outside air is maintained between 15° and 35°C.

A third, much lighter design made use of sheet metal, as shown in Figs. 6, 7, and 8. This plate reduced the weight of the entire assembly considerably and still gave an efficiency in excess of 70 per cent. On one side are the entrance and the exit header. On the other side is the cross flow header that permits the air coming down from one tube to reverse its flow and return in the next tube. Air in the tube is, therefore, going in opposite directions—i.e., the even numbered tubes all have air going in one direction and the odd numbered tubes all have air going in the opposite direction.

The use of these turbulent air cooled plates permits the cooling of electronic equipment at extremely high altitudes. The plate will cool its load efficiently as long as a pressure difference of 1 lb. per sq.in. is maintained. Other plates have been designed for different pressure drops as required by the available air pressure.

Solution of the Second Problem

With the advent of the turbulent air cooling plate, it was now possible to tackle the second problem permitting the reduction in weight of the overall electronic gear in an airplane. A number of solutions to this problem are shown here.

(*a*) *Hermetically Sealed Units*

It is often necessary to construct hermetically sealed units that are to be mounted on a turbulent air cooling plate. An excellent solution that has met with considerable success has been found in the construction as shown in Figs. 9, 10, 11, and 12. In these samples, the chassis has been made a thin casting, and the electronic tubes and other heat-generating components are buried in the wall. For instance, the chassis shown in Fig. 11 has provisions for eight subminiature tubes and two nine-pin miniature tubes. The subminiature tubes are mounted inside the holes by means of rubber inserts that hold the tubes firm at both ends and seal the air inside the tube. It has been found important to eliminate all natural convection in these units to eliminate the possibility of hot spots. By providing an excellent contact path between the heat sources and the turbulent air cooling plate, the overall weight and volume of the equipment was considerably reduced while still maintaining extremely low temperatures at high altitudes. Although the experimental units shown here were made fairly heavy ($^1/_2$ lb. apiece), much lighter designs have been made with sheet metal units, using the same principle. In large scale production, die castings with thin walls would be in order.

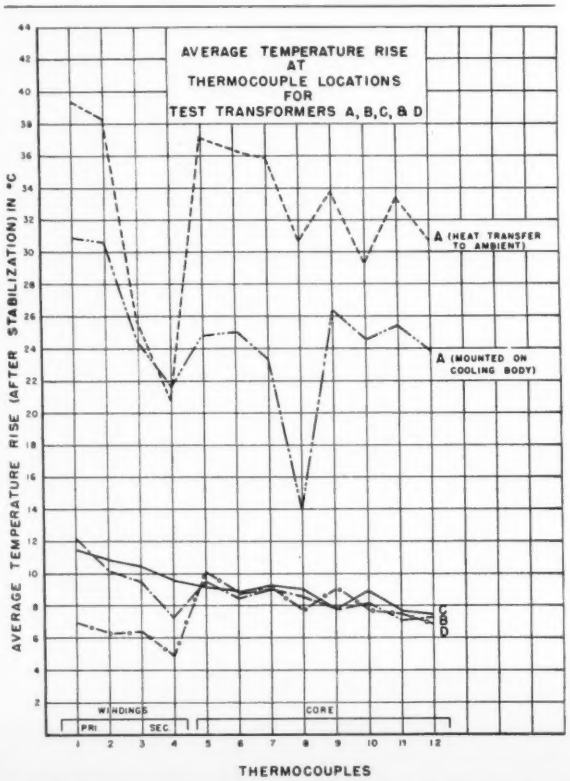
AVERAGE TEMPERATURE RISE AT THERMOCOUPLE LOCATIONS FOR TEST TRANSFORMERS A, B, C, & D
A (HEAT TRANSFER TO AMBIENT)
A (MOUNTED ON COOLING BODY)
AVERAGE TEMPERATURE RISE (AFTER STABILIZATION) IN °C
WINDINGS
PRI.
SEC.
CORE
THERMOCOUPLES

Fig. 17. Temperatures observed at various thermocouples in the transformers.

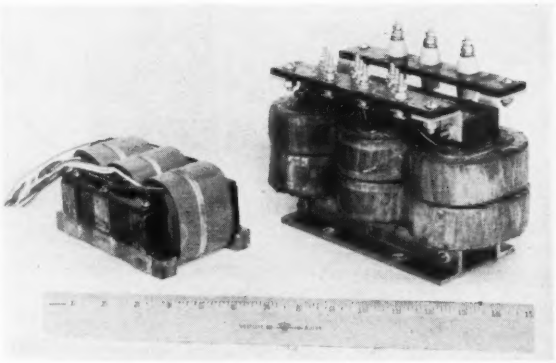

Fig. 18. Interchangeable three-phase plate transformers. Both 1,100 volt amperes, Class A insulation. At right, conventional transformer, weight, 18 lbs., volume, 202 cu.in. At left, directly cooled transformer, weight, 8 lbs., volume, 59 cu.in.

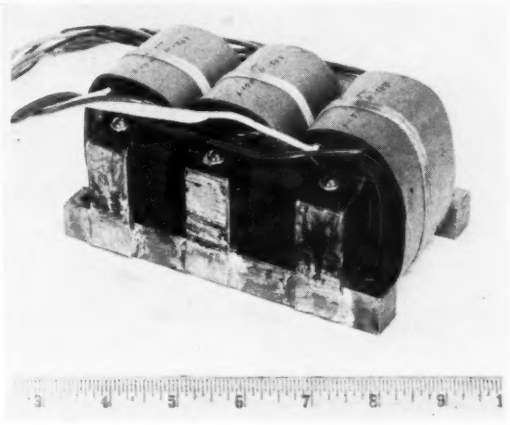

Fig. 19. Directly cooled transformer showing copper conductors coming out of windings.

(*b*) *Transformers*

A considerable reduction in the weight of the transformer and other magnetic components has been made possible by the application of new cooling techniques. Analysis of the heat-generation problem inside a transformer indicates that the main factor that dictates the size of the transformer, other than electrical characteristics, is the amount of heat generated. Part of the heat is generated in the core, and a part of the heat is generated due to losses in the copper. This heat must be removed, and usually the surface of the windings or insulation is used as the radiating or conducting element. A number of transformers were designed in which copper conductors were built into laminations as shown in Fig. 14 or were built into the windings as shown in Fig. 15, or both in the laminations and windings. (See Fig. 16.) These copper conductors were then connected to a conducting bar that mounted on the turbulent air cooling plate. The result of the experiments is shown in Fig. 17.

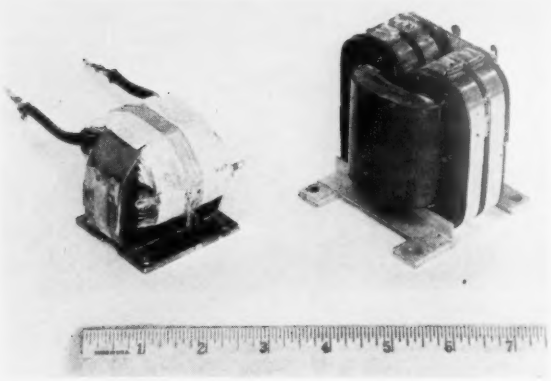

FIG. 20. Comparison of directly cooled filament transformer and conventional model.

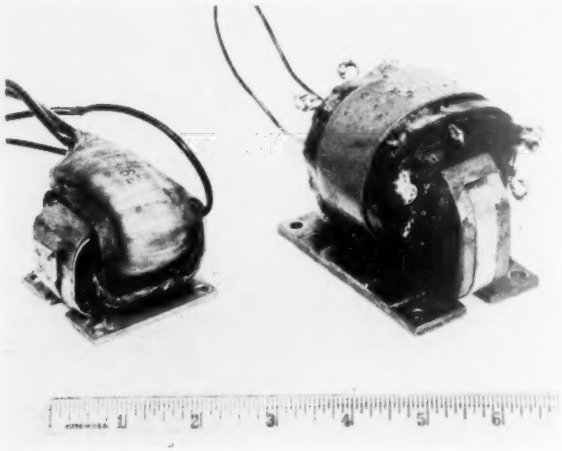

FIG. 21. Two experimental models of small size high-power directly cooled transformers for mounting on cooling plate.

The basis for the experiments was a three-phase plate transformer having a capacity of approximately 1,100 volt amperes. This standard transformer was first used without any modifications (see Fig. 13) except that approximately 12 thermocouples were built into the transformer at various places. A number of transformers were then built identical to the standard transformer, except that heat conductors were added as shown in Figs. 14 to 16, inclusive. It can be seen from Fig. 17 that the temperature rise, especially with the transformer having heat conductors in between the windings, has been enormously reduced.

As a result of these experiments, the transformer was redesigned for smaller size, and the results are shown in Figs. 18 and 19. These two transformers are completely identical in electrical characteristics, and both use Class A insulation. The directly cooled transformer has a maximum temperature rise of 20°C. above the cooling plate (which is 20°C. above ambient), and the standard transformer has a maximum temperature rise of 40°C. above ambient. The weight of the directly cooled transformer, even with the unnecessarily heavy copper bars on the side, is approximately 8 lbs. vs. 18 lbs. of the conventional transformer.

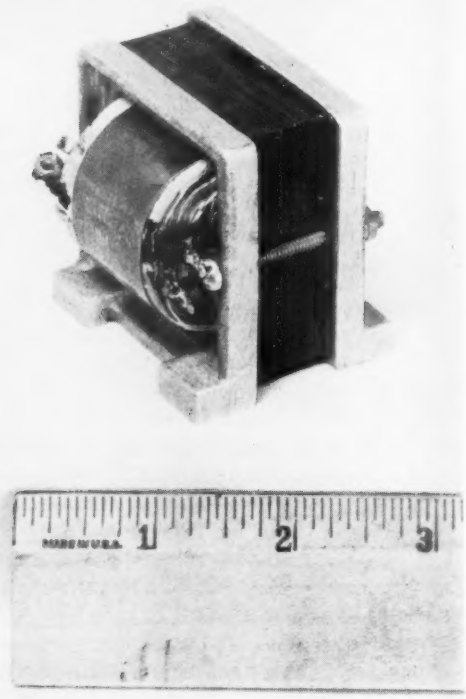

FIG. 22. Miniature transformer using direct cooling techniques.

Further reduction in weight of the directly cooled transformer is being achieved by reduction in size of the side conductors. A number of other transformers have also been built using the same principles as shown in Figs. 20, 21, and 22. In general, introduction of the direct cooling method reduces the weight and volume of the transformer to less than one-half and usually to less than one-third.

It can be seen that the aforementioned techniques—i.e., good heat conduction from the heat source directly to the heat sink—can considerably reduce the overall volume and weight of most electronic gear in aircraft. These techniques have also been applied to other electronic components with similar results. Estimates at present indicate that, in general, the overall size and weight of the entire electronic equipment in aircraft can be reduced to one-third by using these techniques. However, a small additional increase in weight will be necessary for blowers, ducts, etc., so that the overall reduction to one-third may not be completely realized. It is, however, estimated that by the use of these techniques the overall weight of the airplane can be reduced by one-half of the total weight of the entire electronic equipment.

ACKNOWLEDGMENT

Part of the work described in this paper was done under contract with the Armament Laboratory, AMC,

(*Continued on page 81*)

Radomes and Aircraft Design

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U.S. Naval Air Development Center

Introduction

Radomes (radar housings) are dual function components, being at the same time part of the aircraft and part of the radar system. Their design comprises the exercise of aerodynamics, electromagnetics, structures, thermodynamics, consideration of aircraft and radar system design, and materials and processes.

The purpose of this paper is to discuss briefly the effects of radomes on radar performance and aircraft systems performance, the present state of the radome art, and design data of current interest.

It is proposed first to discuss the electrical effects of radomes on radar operation.

Radome Effects on Radar Intelligence

Fig. 1 shows several radomes installed on aircraft, and Fig. 2 shows typical radome constructions. It can be seen that the radome may either be an integral component of the air frame or external to the air frame.

The radome houses a radar antenna or scanner. The antenna radiates energy in the microwave portion of the electromagnetic spectrum at frequencies usually from 3,000 to 30,000 mc. At these frequencies, the radiated microwave energy exhibits the properties of radiated energy in the visible portion of the spectrum, in that microwave beams can be reflected, transmitted, absorbed, or diffracted. Fig. 3 shows a block diagram of a search radar with a large antenna scanning over a wide range of angles. Fig. 4 shows a number of antennas that scan over a more limited range of angles.

The gross effects of the radome on the principal types of radar may now be discussed. These radar may be broadly classified as long-range search radar and short-range homing or intercept radar. For the most part, search radars require large antennas, or reflectors, to obtain high gain and narrow beam widths at the frequencies used. The radiated microwave energy is transmitted in pulses. The pulse repetition rate, P.R.F., is selected so that, in conjunction with selected scan rates, targets may be efficiently illuminated at maximum design ranges. The transmitted beam is usually a few degrees wide in azimuth and wider in the elevation plane.

Long-range search radar scan over a large range of angles in azimuth—up to 360°. Hence, these radar are installed under the fuselage or possibly topside.

Precision radar used for homing, intercept, or tracking have limited antenna scan angles. It is therefore convenient to install these radar in the aircraft nose, the tail, or forward- or aft-looking nacelles, without restricting necessary antenna coverage.

Presented at the Session on Electronics in Aviation—I, Twentieth Annual Meeting, I.A.S., New York, January 28-31, February 1, 1952.

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In all cases, the housing, whether considered to be a primary or secondary air-frame structure, must be nearly transparent, electromagnetically.

If the radome is used with long-range search radar, the primary design requirement is that the radome shall transmit all or nearly all of the incident microwave energy radiated by the antenna. Reflection and absorption of energy reduce transmitted power and, hence, reduce radar search range.

The second design requirement is that the radome shall not modify the antenna pattern appreciably. If, for example, the side lobes of the antenna pattern contain more energy as a result of radome reflection or diffraction, targets may be picked up on the side lobes with resultant confusion as to their direction. Also ground return may be increased, thereby obscuring airborne targets. Fig. 5a schematically illustrates the effect a poor radome has on a search radar antenna pattern by reducing transmitted power and changing antenna pattern characteristics. Fig. 5b is a typical plot of an antenna pattern (relative power versus angle) with and without radome.

There are several radome design manuals available for use to the aircraft designer. References 1 and 2 have been prepared for the design of adequate radar housings for search radar. The design approach is formal and straightforward. It is not necessary therefore to dwell on the procedures for electrical design of radomes used for search radar only.

Of more immediate interest are the electrical effects of radomes on FM/CW and pulsed homing and intercept radars.

Frequency-modulated, continuous-wave (FM/CW) radar, transmitting a continuous modulated signal, is capable of ranging and of determining velocity of selected objects by utilizing the Doppler shift effect of the reflected energy from the moving object under scrutiny. CW systems are sensitive to spurious power reflected back through the radiating system. Power reflected from the radome can obscure echo signals. Also, if the power reflected is sufficient, the magnetron frequency is shifted, with resultant deterioration of the radar intelligence received. Shown in Fig. 6 is a radome housing. For purposes of discussion, a FM/CW antenna is assumed to be shown. Shown also are idealized rays representing microwave energy radiated from the antenna. Part of the energy is transmitted, part is absorbed by the dielectric radome housing, and part is reflected. From the principle of conservation of energy:

$$T^2 = 1 - R^2 - A^2$$

where T^2 = power transmission coefficient, R^2 = power reflection coefficient, and A^2 = power absorption coefficient.

For CW systems, that part of the energy reflected from the radome back into the receiving system must

FIG. 1. Typical radome installations.

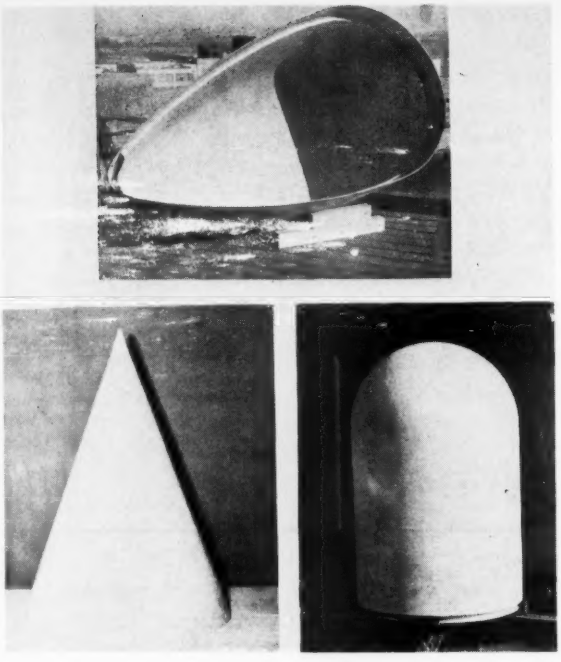


FIG. 2. Typical radome constructions.

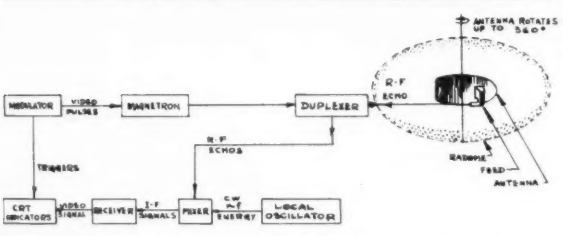


FIG. 3. Radar system used for long-range search.

usually be 40 to 50 db. down from the radiated energy or a ratio of reflected to transmitted power of 0.0000316, approximately. However, more power may conveniently be allowed to reflect from the radome. Most radome shapes are not hemispherical and, hence, do not focus the reflected energy. Instead, energy is randomly reflected, and only a small portion is directed so as to produce mismatch in the radiating system.

Unfortunately, it is not practical to determine the amount of energy reflected from the radome by ray tracing techniques (see references 1 and 2 for discussion of geometrical optic techniques used in radome design) because ray tracing methods, which involve some graphics, are not sufficiently accurate design tools. Small changes in radome dimensions and electrical properties and in the location of the antenna with respect to the radome can cause comparatively large changes in the power reflected back into the CW radar system.

The design of radomes used with CW radar is primarily a problem of minimizing the effect of radome reflection. Current practice is to design for maximum power transmission using methods outlined in references 1 and 2 and to determine experimentally the best combination of radome shape and antenna location which will result in minimum radar system reflection. In general, streamlined shapes with wall constructions comprising electrically uniform thin skins 0.010–0.020 in. (for fiberglas laminates), used alone or in sandwich constructions, are necessary to assure low microwave power reflection.

It is now appropriate to consider that class of radars which may be considered as precision radar—that is, radars designed to obtain highly accurate intelligence on bearing angles to the observed target. Such radars are used in gun laying systems or for homing or terminal guidance of missiles. It is in conjunction with these that the aircraft designer is most interested in the effect of the radome on air-frame design and on systems performance.

Here again it is desirable to consider the radar types used to obtain bearing intelligence.

As stated, the purpose of precision radar is to provide present position and angular rate data, describing the motion of the object observed to some type of computer that compares the radar output signal with a reference value. The difference comprises an error signal that is appropriately used to command the servosystem to operate to reduce the error signal to zero. A block diagram of a missile system is shown in Fig. 7.

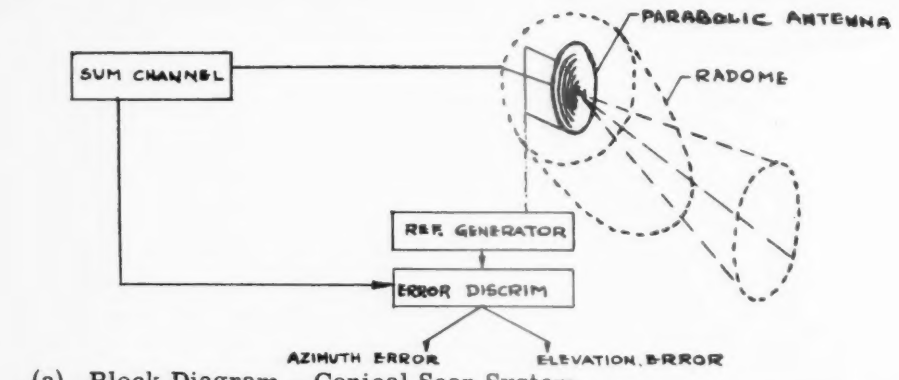
Among the radars proposed for use to provide angular position and angular rate data for gun laying or missile guidance or homing use are the following: (1) conical scan system, (2) phase comparison monopulse system, (3) amplitude sense comparison system, and (4) phase-amplitude monopulse system. These are shown schematically in Fig. 4.

Referring to Fig. 4(a), the conical scan system usually incorporates a mechanically scanning paraboloidal antenna radiating a pencil beam. The antenna rotates continuously about the mechanical axis with the antenna set at an angle to this axis such that the center of the beam describes a cone in space. The included angle is usually less than the beam width (beam width is the angular width of pattern at points on antenna power pattern 3 db. down from maximum power).

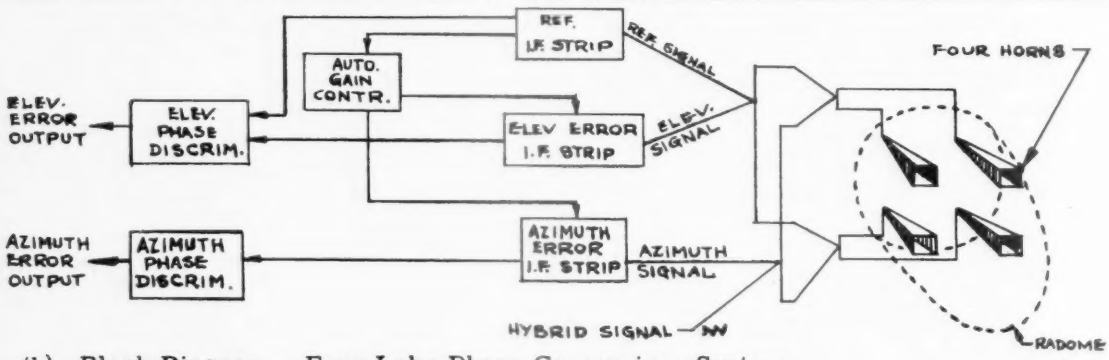
An object falling within the beam during a revolution of scan will return an echo that is amplitude modulated as the beam rotates. The modulated signal is used as an error signal for positioning the antenna. Zero modulation means the antenna spin axis is passing through the target. Angular accuracy of a few mils is possible with this system. Note that it involves continuous mechanical displacement of the antenna with respect to the radome.

Fig. 4(b), (c), and (d) show other systems that can obtain angular intelligence provided the target falls within the beams formed by the radiators used.

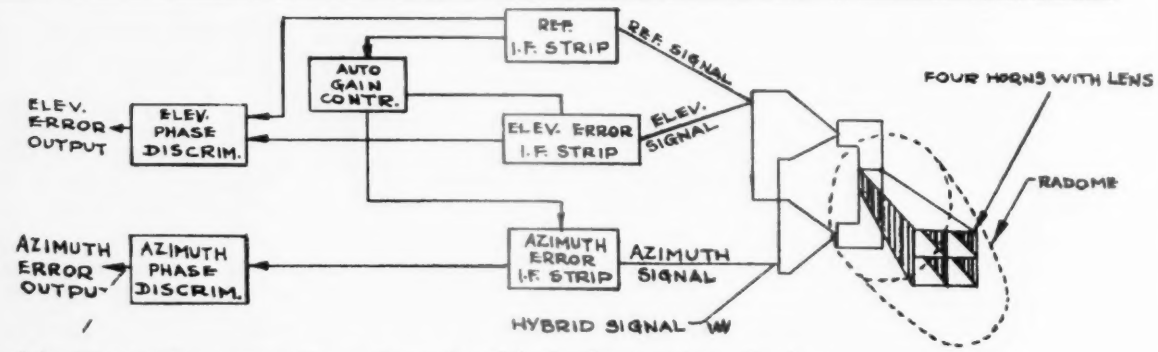
Briefly, so as not to delay discussion of the radome effect, the phase comparison system, Fig. 4(b), compares the phase of the echo voltage picked up by four antennas, spaced several wave lengths apart, to determine direction of target. The amplitude comparison



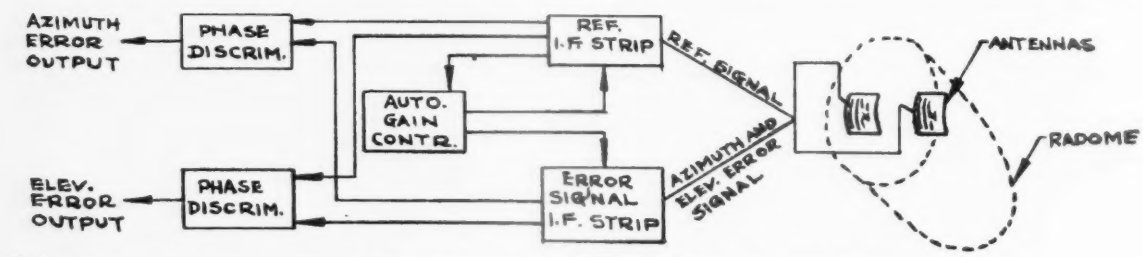
(a) Block Diagram - Conical Scan System



(b) Block Diagram - Four Lobe Phase Comparison System



(c) Block Diagram - Four Horn Amplitude Comparison System



(d) Block Diagram - Two Lobe Phase - Amplitude Comparison System

FIG. 4. Radar systems used for tracking.

system, Fig. 4(c), compares the amplitude of the echo returns from four antennas located at one point (or practically so). The antennas are pointed so their beams diverge. The phase amplitude comparison system [Fig. 4(d)] utilizes two antennas spaced several wave lengths apart and pointed so that the beams converge in azimuth and stack in elevation (i.e., cross section through beams appears as a figure eight). Azimuth angle is obtained by comparing phase of the echo received from each antenna. Elevation angle is determined by comparing the amplitude of the echo received from each antenna. Typical main beams for each type of radiating system are shown in Fig. 8. Essential to the success of each system is the maintenance of the beam characteristics upon which the electronic system design is predicated and the proper utilization of the received echo signal when a target is illuminated. In the conical scan system, it is necessary that the pencil beam pattern remain undistorted during scan if the loci of the null (or crossover points) are to define a point and not an irregular volume. Similarly, with the remaining systems, distortion of the beams results in amplitude and phase differences that unbalance and degrade system performance.

The radome is a component of the radiating system of all the radars described. Unfortunately, it has not been possible, to date, to preserve the antenna patterns associated with the radiating systems described.

The radome is a double curved dielectric sheet inserted in free space (or air) between the antenna and a target. It may reflect, absorb, and diffract the electromagnetic waves it intercepts. The primary objective in designing radomes used in precision radar systems is to select materials, constructions, dimensions, and shapes that will reduce the effect of the radome on the antenna patterns. This is not an easy thing to do at present. The difficulties can be discussed with the aid of a few simple sketches and optical concepts. Fig. 9(a) shows a point source radiator surrounded by a spherical transparent shell. If the point source is at the exact center of the shell, all rays strike the sheet at normal incidence, pass through the shell with no refraction, and emerge only slightly later (due to the specific index of refraction of the shell) than they would if the shell had not been there. Since all emerging rays are delayed in phase by the same amount, the far field pattern will be spherical or the same as it would have been if the shell (or radome) were not present. However, radar antennas are not point sources, and radomes, because of aerodynamic considerations,

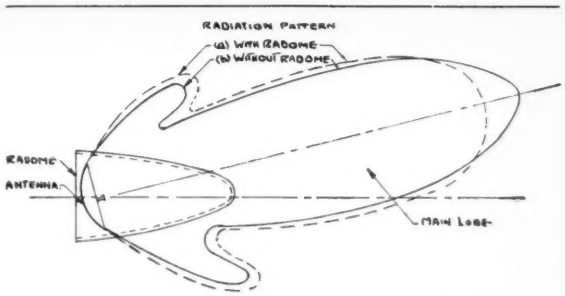


FIG. 5a. Effect of radome on search radar radiation pattern.

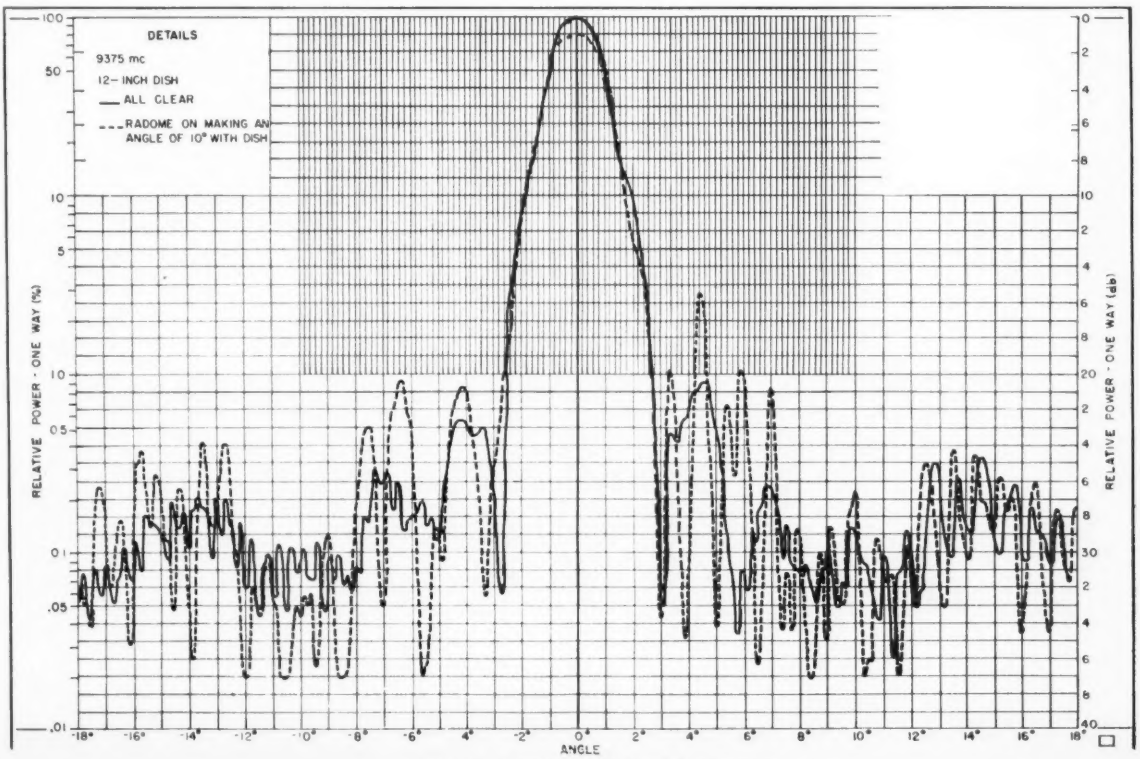


FIG. 5b. Typical radiation test patterns.

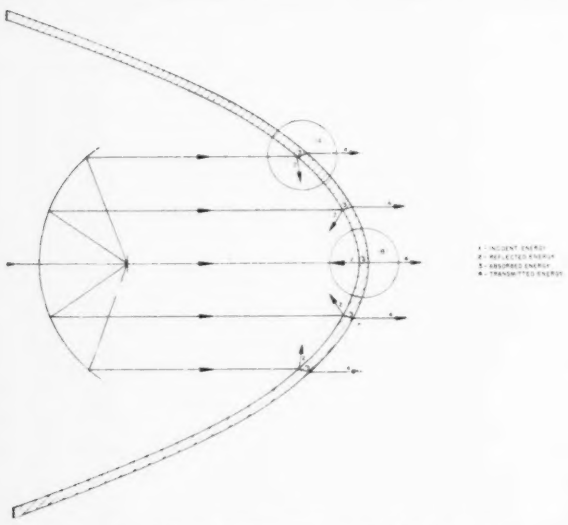


FIG. 6. Reflected microwave energy from radome.

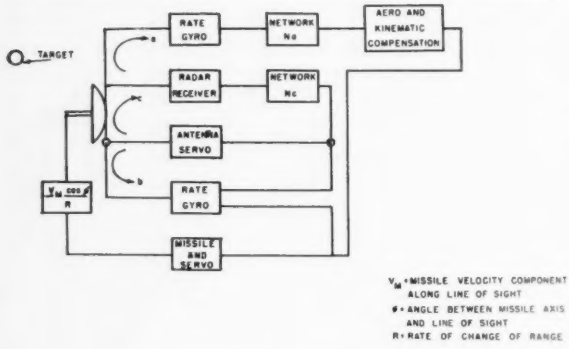


FIG. 7. Semiactive homing missile system.

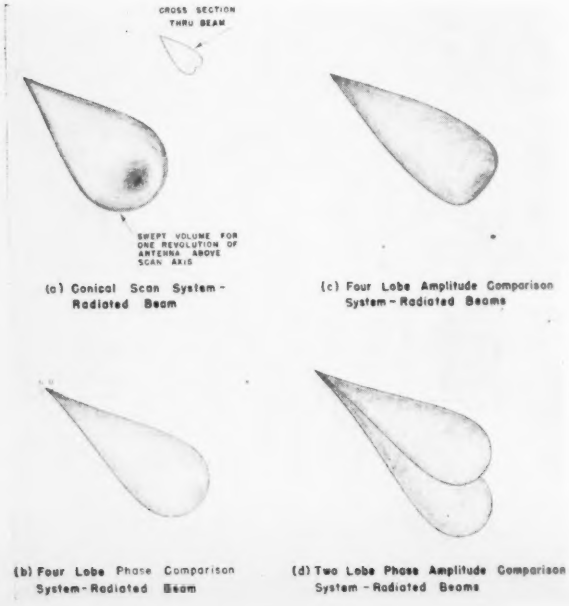

CROSS SECTION THRU BEAM
SWEPT VOLUME FOR ONE REVOLUTION OF ANTENNA ABOVE SCAN AXIS
(a) Conical Scan System - Radiated Beam
(c) Four Lobe Amplitude Comparison System - Radiated Beams
(b) Four Lobe Phase Comparison System - Radiated Beam
(d) Two Lobe Phase Amplitude Comparison System - Radiated Beams

FIG. 8. Antenna beams of several precision radar.

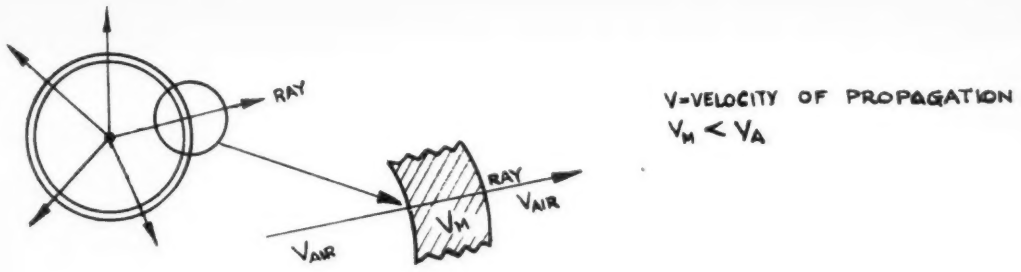
are seldom portions of spheres. Hence, the ray may be partially reflected, absorbed, and diffracted, as illustrated in Fig. 9(b). Also, since all the energy radiated from an antenna may be considered to be contained in a number of parallel rays that illuminate the radome wall at a number of points, one may expect that the individual rays will experience varying amounts of attenuation, reflection, and diffraction due to range of angles of incidence encountered, change in wall thickness as a result of incidence angles, and the changing radius of curvature of the wall because of radome shape. Such is the case. As a result of passage through the radome, all rays are operated on differently, experiencing different amounts of attenuation and diffraction.

Returning to electromagnetic concepts used in radar—if we assume the wave front of an electromagnetic wave incident on the radome to be plane, the emerging wave front will then be distorted. If this distorted wave front is replaced by a number of dipole radiators, radiating with the same amplitude and phase as the rays they replace, the far field pattern can be computed in principle and compared with the pattern for the antenna without radome. The patterns will differ.

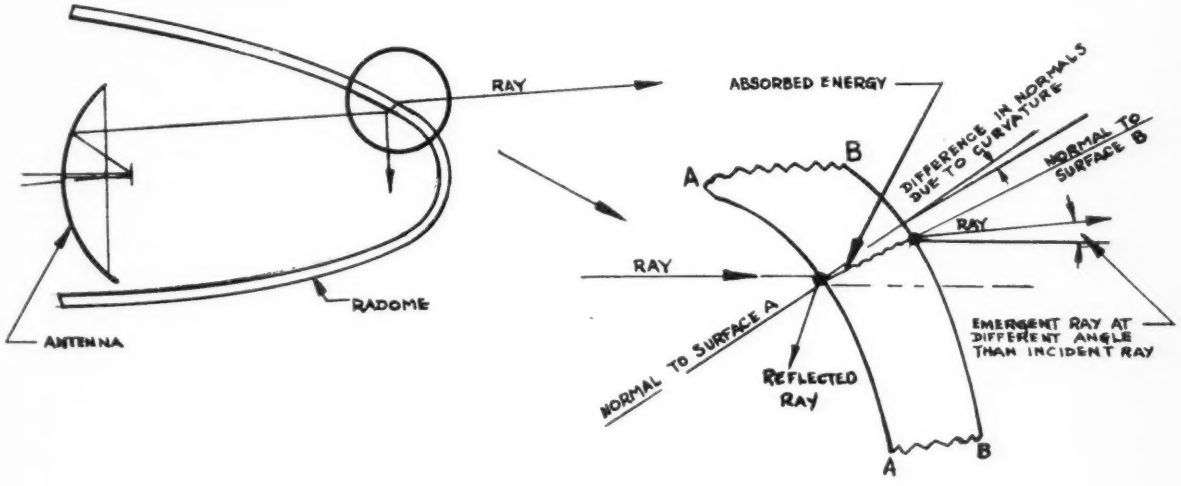
In the foregoing problem, current design procedure is to: (1) select low loss materials—i.e., materials that absorb little microwave energy at the frequency used in the radar, (2) select materials having low dielectric constants to minimize phase differences, and (3) select constructions and wall dimensions that will result in minimum power reflection over the range of angles of incidence which exist. References 1 and 2 contain useful electromagnetic theory and procedures for a partial solution of this problem but cannot be used for the whole solution. The difficulty can be explained by the fact that the use of geometric optics, adequate for the generalized solution of the radome transmission problem, is not adequate (or at least has not been proved adequate) for the solution of the radiation problem introduced by the presence of the radome in the radiating system. To be more specific, if the design steps mentioned previously are followed, a reasonably good radome design will be obtained, but it will not be known whether the resulting design satisfies the requirements of the system.

Because of the dilemma, the present consensus among designers is to design for minimum reflection, maximum transmission, minimum absorption, and minimum phase shift and then to look elsewhere for ways to reduce the impairing effect of the radome.

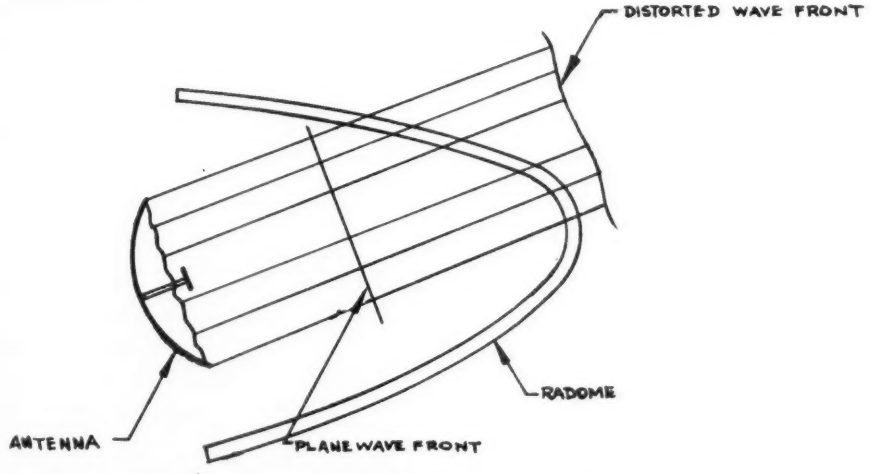
Other places to look are in the overall system of which the radome is a part. The system may be a gun laying system or a missile system. These are inherently the same. In both, the objective is to direct a projectile to a target. In the gun laying problem, the problem of directing the projectile is done once, and in the missile problem, continuously. In both, however, data relating to the angular direction of the target and angular rate of change of the target must be accurate.



(a) Point Source Radiator and Transparent Shell

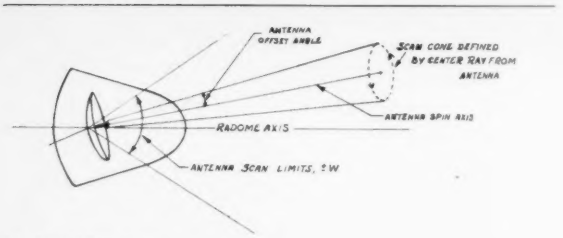


(b) Effect of Radome on Incident Ray

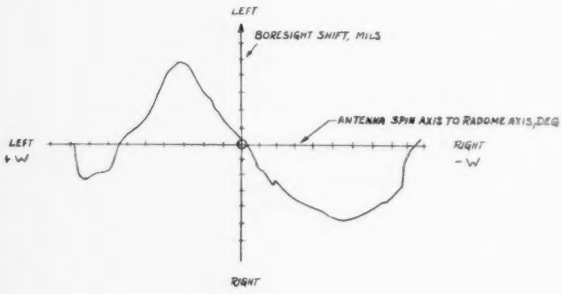


(c) Distortion of Electromagnetic Wave Front Due to Passage Thru Radome

FIG. 9. Radome effects on radiated electromatic energy.



(a) Conical Scan Antenna



(b) Boresight Shift Due to Radome Vs Antenna Spin Axis Position

FIG. 10. Boresight shift due to radome.

Shown in Fig. 10(a) is a sketch of a radome housing a conically scanning antenna, and below, Fig. 10(b), is a representation of a typical boresight shift curve (or null shift curve). Points on the curve are obtained by electrically aligning a radar transmitter and receiver by nulling the crossover point and then noting the variation in the position of the crossover point when the radome is placed in front of the transmitting antenna and progressively rotated in azimuth to simulate relative motion between antenna and radome. The rate of change of null point deflection (mils or degrees null point shift per degree change in antenna heading) in poor radomes may be as high as 2 mils per degree, and the magnitude of the error may be a significant fraction of a degree or more. For clarity, a single beam shift curve is shown in Fig. 10(b). However, in practice, another curve of boreshift showing vertical deflections would be plotted. In other words, the boreshift produced by the radome has vertical and horizontal components.

Since, in a conical scan system, the radar seeks a null signal (unmodulated) and is on null when it is on target, a shift in the null means a boresight error—i.e., a false target position—and a changing boresight shift error with changing antenna heading means false information on change of target bearing. A boresight shift error increasing to the left as the antenna changes heading to the left results in information that the target velocity is greater than it actually is. Similarly, a boresight shift to the right as the antenna scans to the left means target velocity is less than true target velocity. This false information is fed to computers. In gun laying systems, the magnitude of the boresight shift error as well as its rate of change can cause appreciable system error, aside from the possible effects on the stability of the system. Fig. 11 shows a family of curves from which miss distance may be determined if the radome rate error is known. To this distance should be added or subtracted the distance due to the instantaneous radome error.

The foregoing remarks concerning radome error are applicable to the other radar systems discussed. Effects on the tracking accuracy of the system may be expected because the radome will distort the main beam in all cases.

In passing, it is desirable to point out that although each of the radar systems described differs in many respects, it cannot be assumed that a radome found satisfactory for use with one system will necessarily be satisfactory if used to house some other radar system. Important parameters in radome design are antenna size, antenna scan angles, radar frequency, type of polarization, location of antenna within the radome, etc. A complete design and test evaluation of an existing radome is in order if it is being considered for use with a new radar.

MISSILE AND AUTOMATIC AIRCRAFT SYSTEMS PERFORMANCE

Of direct interest to aircraft designers is the attitude stability and flight path stability of unmanned aircraft. In such machines, equipped with homing or terminal guidance radar, the effect of inaccurate angular bearing rates may seriously affect system performance. In particular, systems that are designed to direct the mis-

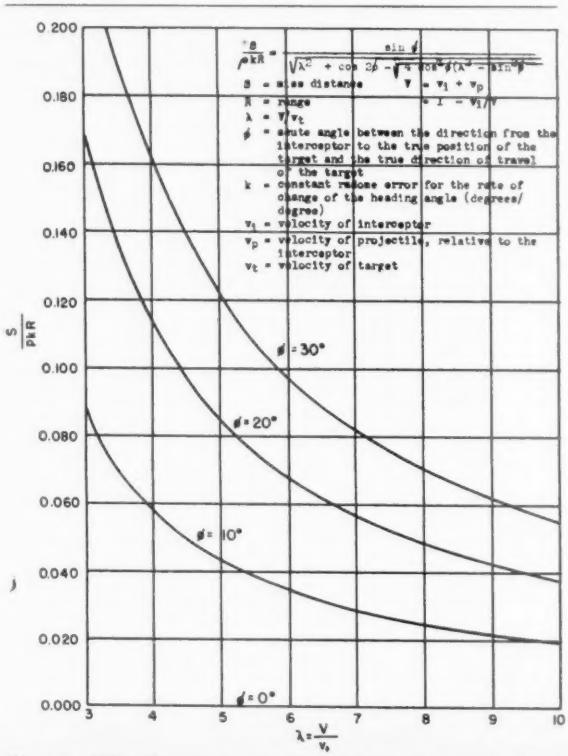


FIG. 11. Miss distance as function of radome rate error (degrees per degree) for interceptor aircraft.

sile on a proportional navigation trajectory are affected by the radome angular tracking errors.

One such system is shown in Fig. 7. a, b, and c are the missile control loop, antenna stabilizing loop, and the receiver tracking loop, respectively. In loop c, the radar receiver output is used to position the antenna so as to track the target. In loop b, the antenna platform orientation is adjusted so as to fix it in space if the missile heading is disturbed. In loop a, the angular motion of the antenna in space is measured by the rate gyro, and the outputs are fed to the missile control servos to effect change of missile heading until the rate of change of heading is zero. The term $(Vm \cos \theta)/R$ represents the geometry describing the contribution of the missile to rate of change in range.

Because the intelligence the radar gathers is angular information, it can be seen that a given translational displacement of the target from the present line of sight and along its flight path will cause a larger angular displacement of the antenna in seeking a new line of sight as range decreases. Therefore, as range decreases, the system gain will increase. In practical missile control systems, the change in gain which can be tolerated is limited by air-frame and component resonances. If the radome can cause a target shift as the antenna scans from one line of sight to a new line of sight, as the range decreases, the radome rate error may cause the system to become unstable through its effect on gain.

The radome rate error also affects system performance through its effect on the navigation constant λ (proportionality factor between missile rate of turn to rate of change of line of sight to target). If, for example, the antenna moves azimuthally with respect to the radome and the radome rate error causes a fictitious shift in target position, the missile will be directed on a new course calculated to intercept the false target. The effective navigation constant, which results from the radome rate error, is defined as $\lambda' = \lambda \left(\frac{1-k}{1-k\lambda}\right)$, where k is the radome rate error in degrees per degree. A positive radome error—that is, an increasing value of boresight shift in the same direction as antenna scan—causes an increase in navigation constant. Physically this means the missile is commanded to turn at a greater rate than it ordinarily would if the radome rate error were absent. Similarly, a negative radome rate error will result in a smaller effective navigation constant than the true navigation constant. Since the navigation constant is a parameter of the missile feedback control system, a change in the feedback control characteristics can establish the condition for instability of the control system. Depending on response times and phase relationships that exist among the electronic, mechanical, and aerodynamic portions of the system, instability may be realized at one or more frequencies. Instability may be evidenced at aerodynamic frequencies and at low frequencies. In the first case, the effect will be missile attitude oscillation and in the second, flight path instability evidenced by wide swings from the intended flight path.

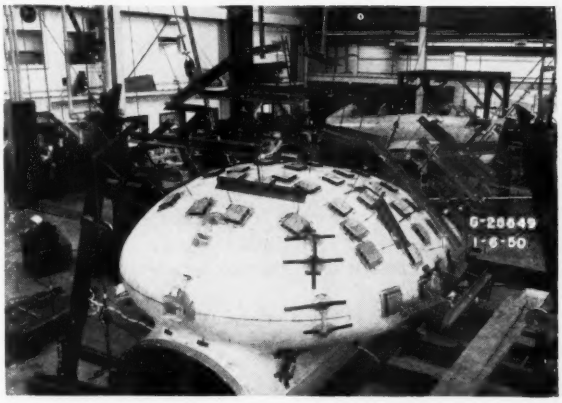


FIG. 12. Radome static test setup.

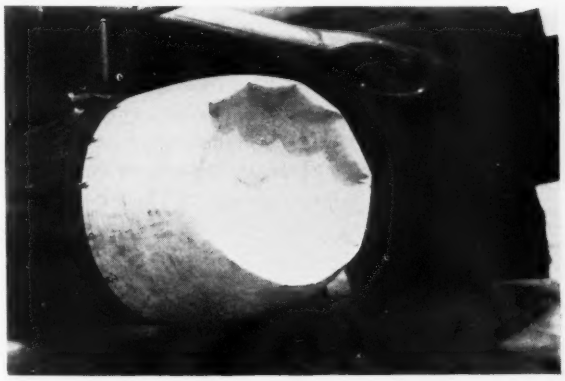


FIG. 13. Radome damaged by gun blast.

Although it is currently conceded that no rigorous analytical method exists for the electrical design of radomes used with precision radar, the use of existing geometrical optical theory, which permits examination of a proposed design through examination of the attenuation, diffraction, absorbtion, and phase shifting effects on transmitted electromagnetic energy, the extensive use of beam deflection test equipment, the exercise of quality control to obtain uniform and reproducible radome material and structural characteristics, and the relaxation of aerodynamic and structural requirements, where necessary, has been found effective.

AERODYNAMIC AND STRUCTURAL CONSIDERATIONS

Although the electrical design of radomes is in itself a formidable problem, it is further complicated by aerodynamic and structural requirements. Good electrical radome shapes and constructions are not necessarily good aerodynamic or structural designs.

Electrically, hemispherical shapes with walls made of a low dielectric material a few thousandths of an inch thick would meet nearly all current design requirements. However, this design is unacceptable aerodynamically or structurally for most current radar installa-

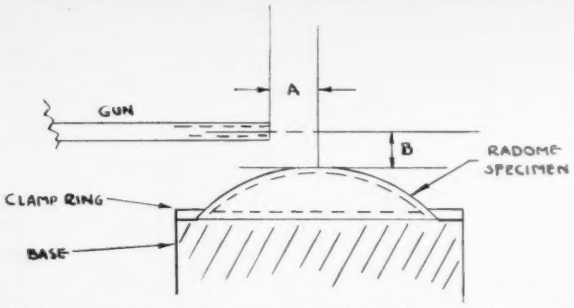


FIG. 14. Gun blast test setup for typical radome constructions.

tions in aircraft. A compromise design is the only alternative.

Some evidence exists[3] which indicates that the aerodynamic characteristics of nose shapes are not significantly changed with moderate blunting. Further experimental data may indicate the possibility of additional blunting.

Beyond this possibility, systems performance may actually be improved if aerodynamic efficiency suffers somewhat. In other words, if radar performance is improved at the same time aerodynamic performance is impaired, the resulting effect on the system may be an improvement in overall performance. There has been a tendency in the past for the electronics engineer to consider only his equipment in the system and the aerodynamicist to consider aircraft performance as defined by speed, stability, etc. The systems engineer must balance the conflicting requirements.

To a lesser extent, the conflict between electrical and structural requirements poses the same problem. In most cases, a radome designed for electrical performance is satisfactory structurally. However, there are cases where structural design requirements must prevail. But, the structural adequacy of a proposed radome design is difficult to evaluate using classical methods of stress analysis. Although the physical properties of the materials and constructions used may be determined, the accurate calculation of the stresses due to the applied loads is not possible. Radomes are complex shell structures, which also partake of some of the properties of membranes. Analytical methods of analysis of shell structures apply only to the simpler forms of structures, such as flat elements and cylindrical elements, and to walls of isotropic characteristics. Their use for the analysis of radomes entails simplifying assumptions that justify doubts as to the accuracy of the results. In almost all cases where a serious attempt has been made to stress-analyze a radome, the resulting design has been found to be unduly conservative when static tests were run. It is therefore good design practice to underdesign a radome structurally, making use of structural analysis as a preliminary design aid only. The strength of a radome can be accurately determined at such time that a physical specimen has been constructed and static tested.

Although this approach may offend the sensibilities of stress analysts, it is nothing more than recognition of the fact that there are limitations in the present art of stress analysis.

Well-known static test procedures are adequate for radomes. Fig. 12 shows a static test fixture for a large radome. Since there is an indefinite spread between yield and ultimate strengths for many plastic laminates and sandwich materials, it is standard practice to use the same ratio of applied to ultimate load used for metals—i.e., 1.35.

In addition to the ultimate strength of a radome, it is frequently useful to measure deflections. Excessive deflections may result in physical interference of the scanning antenna and radome during flight. Deflections also may cause changes in the beam shift characteristics of the radome. In one case it has been found experimentally that small deflections of radome shape of $^1/_{16}$ in. caused boreshift errors of as much as three mils.

Environmental Factors

The service life of a radome is dependent on the severity of the environmental conditions and the ability of

TABLE 1
Effect of Elevated Temperature on Microwave Transmission Through Several Flat Panels and a Radome

Panel No.	Incident Angle	Skin, In.	Core, In.	Microwave Transmission			
				Per Cent	Temp. (°C.)	Per Cent	Temp. (°C.)
35	Normal	0.030	0.850	98	82	94	196
	30°			92	60	88	200
71	Normal	0.030	1.530	79	84	73	187
	30°			74	85	69	195
131	Normal	0.040	0.300	90	116	80	184
	30°			88	50	82	160
138	Normal	0.070	0.400	54	65	27	146
	30°			38	67	33	181
140	Normal	0.070	0.500	54	119	44	170
	30°			31	75	27	183
141	Normal	0.070	0.600	79	90	66	195
	30°			36	75	34	174
142	Normal	0.080	0.350	57	66	46	180
	30°			35	80	31	180
Waffil	Normal	0.030	0.300	98	60	91	187
Conical radome	Normal	0.030	0.420	91	30	77	225

NOTE: All of the panels listed above were of honeycomb-fiberglas sandwich construction except the one indicated as "Waffil," a relatively new type of core construction.

the radome to resist deteriorating effects. The environmental conditions that may require consideration are: (1) aerodynamic heating, (2) weathering (i.e., sunlight), (3) humidity, (4) rain, (5) gun blast, and (6) ice.

Aerodynamic Heating

Organic materials in current use for radome construction are polyester resins, alkyd-diisocyanate resin foams, phenolic resins, rubber foams, etc. Inorganic materials are fiberglas mat and cloth and cast glass.

All these materials, with the exception of the cast glass, deteriorate at temperatures in the range from 175°–500°F. Deterioration of the materials at elevated temperatures is evidence of rearrangement of the molecular bonds and pyrolysis. Hence, not only are physical properties affected, but electrical properties change. The effect of such changes on radomes for precision radar may be similar to random variations in wall thickness, material density, etc., in a poorly made radome. Heating of a radome therefore may deteriorate radar range.

If the listed materials are used, the effects of heating should be experimentally investigated early in the design to determine whether heating of the radome can be tolerated. Table 1 shows the effect of heating on electrical transmission of flat dielectric panels and also a conical fiberglas radome. Heat was applied assymetrical in simulation of a yawed flight condition. Although little data are available to indicate the effects on boresight shift, it can be assumed that aerodynamic heating will contribute to deterioration of radome performance.

Gun Blast

When guns are mounted close to the radome, the effect of gun blast requires consideration. Fig. 13 shows a radome that was partly destroyed as a result of gun blast. Twenty-mm. guns were mounted parallel to the radome axis of symmetry and 11 in. from the nearest point in the surface.

For all but the simpler idealized cases, the calculation of the resistance of a structure to gun blast yields no practical results. Some 32 parameters must be considered. It has been found expedient to rely on gun blast tests to determine the resistance of radome materials and constructions. The straightforward approach, of course, is to flight-test a given gun and radome installation to observe radome performance when subjected to combined air and gun blast loads. This method, however, may be dangerous and expensive and provides data for one installation only, of little value for another radome design.

On the other hand, a complete evaluation of all possible radome materials, constructions, and shapes to determine their performance with all types of guns, location, etc., is not practical. In an attempt to provide some data useful for design, the Naval Air Development Center evaluated six constructions designed for good transmission at 10,000 mc. (a commonly used frequency). A 20-mm. gun was used. Maximum number of rounds fired per specimen was 200. Variables were spherical radius of curvature of the laminate and distance of gun muzzle from specimen. Fig. 14 shows the test setup. Fig. 15 shows test specimens, and Table 2 shows test results. Although the tests were not extensive, it is believed the information obtained is useful. Main conclusions are:

(1) The effect of different constructions in flat panels is not pronounced. In general, all constructions are unable to withstand blast pressures greater than 20 to 30 lbs. per sq.in.

(2) Construction C (mat laminate) withstands higher blast pressures, for radii of curvatures from 15 to 30 in., than other constructions.

(3) The effect of constructions on $7\frac{1}{2}$-in. radii panels is not pronounced. All constructions apparently can withstand a blast pressure of approximately 70 lbs. per sq.in.

(4) Tests indicate that gun muzzles should be located a minimum of 10 in. from flat radome sections

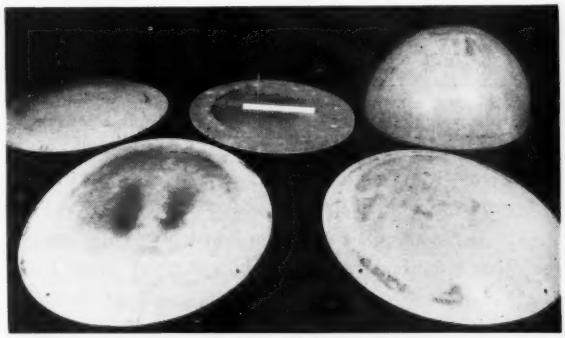


Fig. 15. Gun blast test specimens.

Fig. 16. Radome designed for thermal deicing using engine exhaustheat.

TABLE 2
Gun Blast Test Results*

Blast Pressure, Lbs. per Sq.In.	Spherical Radius, In.				
	Flat	30	22½	15	7½
90		C 3†			
80					
75				B C 4.5 4.5	B 4.5
70		E A C 6 6 6	B 4.5	C 6	A B C E F 6 6 6 4.5 6
65					C D 6.5 6.5
60				B 3	
50					C D 7.5 7.5
40					
30	C F 4 10.5		C 9	A E 9 9	
25	F 9 B 9				
20				D 10	
10		D F B 12 12 12	F 12	F 12	

Radome Construction
A—Standard laminate 4 × 182 glass cloth 50/50 P43/P13.
B—Standard sandwich 3 × 181 glass cloth skins, P43, 0.28-in. Westplak B-8 core.
C—Mat laminate M503 glass mat 75/25 P43/P13.
D—Nylon-glass laminate 2 × 128 glass cloth, 1 × 018 5N nylon cloth, 2 × 128 glass cloth.
E—Staple fiber laminate 1 × 128 glass cloth, 2 × 294 glass cloth, 1 × 128 glass cloth, 50/50 P43/P13.
F—Flexible sandwich 4 × 128 glass cloth skins, 0.35-in. Westplak B-8 core, 50/50 P43/P13.

* Plot includes only radomes withstanding 200 rounds of firing.
† Numbers under radome constructions refer to B dimension as shown in Fig. 14.

and 7 in. from sections having a spherical radius of 7½-in., regardless of method of construction.

(5) Safe distances from the gun to radome surface for other spherical radii may be obtained from Table 1.

WEATHERING

The plastic laminates currently in use have good weathering properties. Extensive tests by North American Aviation, Inc., and others indicate no deterioration in the physical properties of the materials in use. A large collection of radomes at the N.A.D.C. which have been stored outside for several years show no signs of deterioration.

HUMIDTIY

Absorption of moisture by radome materials in current use is evidenced by its effect on electrical and structural performance. In general, plastic laminates with fiberglas filler reinforcements are satisfactory electrically. Lesser used materials such as alkyd-diisocyanate foams used for sandwich core materials may absorb water. Currently it is assumed these materials are acceptable if water absorption at equilibrium, 100 per cent relative humidity and 125°F, does not exceed 6 per cent. However, since little evaluation work has been performed to determine allowable water pickup limits in materials used for precision radomes, it is encumbent upon the designer to consider the humidity factor and test for its effect on electrical performance for each specific design.

RAIN

Of the various environmental factors listed, rain may be most serious. Unprotected plastic laminates have short life in rains if aircraft speed is over 350 m.p.h. approximately. Up to 600 m.p.h., elastomeric or flexible type coatings have been found to prevent delamination and erosion of the laminates. Current rain erosion coatings specifications[4,5] call for neoprene compounds.

At higher speeds, above 600 m.p.h., effective protection from rain is a subject of current investigation by the Air Force and others.

ICE

On transport aircraft and other long-range, all-weather aircraft, icing always has been a hazard. If such aircraft are equipped with radar, icing of the radome can affect the performance of both search and tracking radar. Ice thickness up to 6 in. has been observed.

At present, little operational experience exists to determine the effectiveness of various ice prevention or disposal methods. Use of deicing boots on radomes has been tried and found impracticable electrically. Anti-

icing solutions have been tried and provide limited protection.

Currently thermal deicing is under investigation. Fig. 16 shows a radome built by the Douglas Aircraft Company. The collector shroud conducts air heated by exhaust gases to the nose of the radome. The hot air passes between the sandwich skins and exhausts through holes near the radome base. This construction is practical, structurally and electrically, and shows promise for deicing. Flight tests are being conducted at present. If successful, the construction shown may be adopted for use in radomes on long-range Naval aircraft.

It can be concluded that radome design must be conducted through the cooperative efforts of the radar designer, the air-frame designer, and the systems engineer. Since all are handicapped by the lack of rigorous analytical tools for electrical, aerodynamic, structural, and environmental evaluation of a proposed design, adequate designs require considerable discretion on the part of the design team and, in addition, compromises.

Recognition that radome design is a challenge to all engineering groups may accelerate radome development work and result in more satisfying design procedures.

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Automatic Flight Control

(*Continued from page 31*)

time constant filter was introduced in the beam signal, and a limit of 3° was placed on ordered bank angle. This system was placed on the simulator where step functions of beam error and wind were inserted.

With a step function in beam of $^1/_2$ dot, the path error at zero time was $^1/_2$ dot. The error subsided to 5 per cent of its initial value in approximately 12 sec. The path error due to a wind step of 31 m.p.h. never reached higher than $^1/_{16}$ of a dot.

Using a more conventional arrangement for the automatic control system, under similar conditions, the error as a result of a 31-m.p.h. wind gust was over one dot, compared to $^1/_{16}$ of a dot for the previous method. The response to a beam error step was comparable.

In order to corroborate this theory that was discovered on simulator equipment,we have installed appropriate automatic control equipment in a jet fighter aircraft, and we expect to have some actual flight data on this method shortly.

Summary

In summary, it is believed that the major recent advances in automatic flight control are:

(1) Design of control equipment with more complete dynamic information about the other components involved. This, coupled with system design, will ensure the successful dynamic performance of control systems, in distinction from the frequent requirement for "fixes" that are necessary.

(2) Recognition of the possibility for ground stability in track control through aerodynamic means

(3) The concept of artificial stability.

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Heat-Transfer Design Problems in Aircraft Electronic Equipment

(*Continued from page 68*)

Wright-Patterson Air Force Base. The help of Capt. R. W. Rothammer and E. F. Shell is gratefully acknowledged.

Many thanks go also to J. F. Moore, G. Mathis, R. Maartmann-Moe, R. G. Haagens, R. S. Quimby, and K. Lagerloff, Raytheon Manufacturing Company, who helped in the design and testing of the units described. The consulting services of Prof. J. Kaye, Massachusetts Institute of Technology, were greatly appreciated in the speedy solution of many problems.

Design Limitations on Aircraft Antenna Systems

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THE MODERN MILITARY AIRCRAFT is, as everyone knows, a highly complex device. The reason this is so is simply because it has a highly complex job to do. It must fly faster, higher, further and in greater extremes of weather than its predecessor of a few years ago. It must haul a bigger pay load, carry a more powerful armament, and deliver its more expensive ordnance more accurately than would have been believed possible 10 years ago. As the requirement for all these features has grown, so has the demand for increased performance of the air-borne radio equipment on which, almost entirely, its command, guidance, and navigation must rely. The inevitable result of these pyramiding demands is to create a situation in which the only measures by which the design requirements can be met are seemingly prohibited by the design objectives themselves. This, apparently, is the situation that the designer of air-borne radio equipment now faces.

This problem is not unique to electronic engineers. A similar situation exists for those responsible for structural design, power plant, and armament and in many other fields. The electronic designer's problem has its own special feature, however. All of the others just mentioned are traditionally, and in practice, voting members of the design team. The electronic engineer, and especially the unhappy soul who is responsible for aircraft antenna design, is an outsider. In all too few cases is he drawn into the development before virtually all of the structural and mechanical design has been frozen. By the time he is called in, the limitations of space, weight, and configuration which circumscribe the possible approaches to his problems may be so severe as to prohibit effective solutions. At best, he may be able to shoe-horn into the air-frame antenna designs that were marginal in meeting requirements established 10 years ago. The extra performance demanded by the more advanced mission of the new aircraft is foredoomed.

It is the purpose of this paper to review, in rather broad terms, the minimum antenna design requirements for various aircraft radio systems in current use and to attempt to state, in terms familiar to those responsible for the structural and mechanical phases of aircraft design, the minimum demands that the antenna designer must make for space, location, and configuration if he is to be able to do his job at the present state of the art.

Antenna systems for aircraft can be classified in a logical way into three categories: systems for low frequencies, medium high frequencies, and very high frequencies. For the purpose of this paper, at least, no more elaborate subdivision is required. By low frequencies, I mean here those for which the maximum overall dimensions of the air frame are small compared with the operating wave length. By medium high frequencies, I mean those at which the maximum dimensions of the air frame are of the order of a wave length. By very high frequencies, I mean the region where the wing span, for example, is extremely long compared with the wave length. It is obvious that the antenna for a particular radio equipment operating at a particular frequency may fall in one or the other of these three categories, depending on whether it is to be installed on, for example, a B-36, an F-92, or an air-to-air missile. For the most part, then, the antenna design chosen must be chosen on the basis of the size of the air frame on which it is to be used.

Low-frequency antennas—that is, those used when wave length is large compared with the size of the air frame—always have figure-of-eight radiation patterns. Loop types and dipole types differ, of course, in the orientation of the pattern with respect to the antenna elements and in the direction of polarization of the radiated electric field. For these elementary antenna types, located in free space remote from any conducting body, there is always a fixed and obvious relationship between the orientation of the radiation pattern and the orientation of the antenna element. In the aircraft case, there is no such simple relationship between the orientation of the antenna element and the radiation pattern. The presence of the air frame distorts the electric and magnetic fields in its vicinity and, in so doing, modifies the voltage or current induced in the antenna element so that the radiation pattern is reoriented and the effective length is altered from its free space value. It is important to see how these results may be predicted analytically or through experiment. At low frequencies, as we have defined them here, the intensity and direction of the electric and magnetic fields in the region containing the air frame are nearly that which we would observe if we were dealing with electrostatic, rather than radio-frequency, fields. It can be shown that, when this is the case, the sensitivity of a receiving antenna is proportional to the charge

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* Assistant Chairman, Department of Engineering

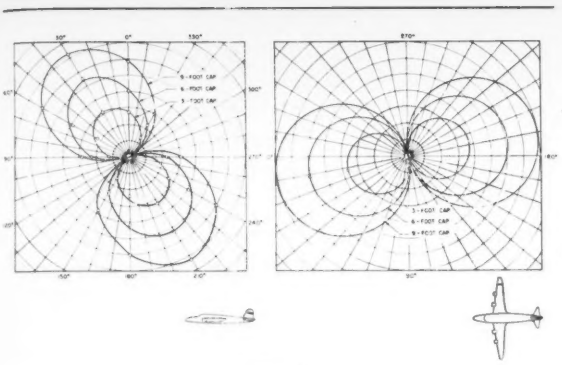

FIG. 1.

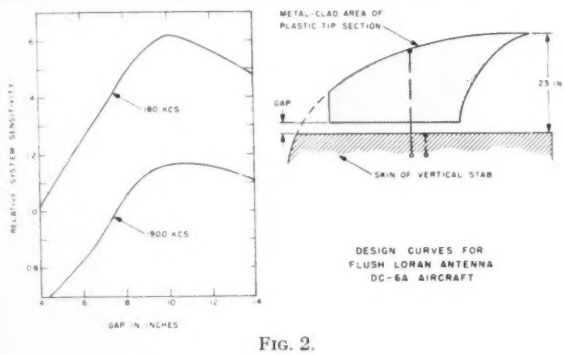

FIG. 2.

that would be induced on it if the aircraft were placed in the field of a large parallel plate capacitor, energized with a d.c. voltage. The fact that this charge would depend on the orientation of the aircraft in the d.c. field is simply the result of the radiation pattern of the antenna. In fact, the data on low-frequency antenna performance which appear in Figs. 1–4 were obtained in this way—that is, with a d.c. pattern range.

Fig. 1 shows the measured low-frequency performance of several wing-cap and tail-cap antennas on a C-54. The right-hand figure shows the radiation patterns of three tail-cap antennas of different lengths. The patterns are shown for the fore and aft vertical plane. Their figure-of-eight shape is obvious, as is the fact that they are not oriented in any obvious relationship to the air frame. The antenna sensitivity is proportional to the magnitude of the patterns shown. This is the quantity that is proportional to the induced charge in the d.c. case. It is not hard to show that the sensitivity, or induced charge, is also proportional to the product of antenna capacitance and effective length—parameters that may be more familiar. It is also possible to show that, if these antennas were used as transmitting antennas, their input conductance is proportional to the square of the maxima of the radiation patterns as plotted here. The figure on the left shows the horizontal plane patterns of a series of wing-cap antennas. The rapid increase in antenna sensitivity and, therefore, of antenna conductance with increasing cap length is obvious.

To be useful for Loran reception, a low-frequency antenna must respond to vertical polarization, have an omnidirectional pattern in azimuth, and have a sensitivity such that, when used with a standard coupler—the CU-167A for Air Force applications—it produces an output voltage of 7 microvolts in an r.f. field of 10 microvolts per meter. The tail-cap antennas illustrated here meet the first two of these requirements. Investigation has shown that a cap length of 2 ft. will satisfy the sensitivity requirement also, provided the proper configuration is chosen for the isolated portion. Fig. 2 shows the effect of the configuration on the performance of a 2-ft. tail-cap Loran antenna on the DC-6A aircraft.* A series of measurements was made on a tail cap of the general shape shown in the right-hand figure to determine the effect of the height of the gap on the sensitivity of the receiving system. Changing the dimensions of the gap does not appreciably change the effective height of the antenna in this case but does change the antenna capacitance. The results are shown on the left. It is readily seen that there is an optimum value for the gap dimension for this configuration. It turns out to be approximately one-half of the vertical extent of the antenna element. The difference between the sensitivity at 180 kc. and at 1,900 kc. is due to the nature of the input circuit of the receiver coupler and to the difference between the Q's of the coils used to resonate the antenna at the two frequencies.

In another important air-borne application of low frequencies, the automatic radio compass, the tail-cap antenna is not satisfactory. The tilt of the radiation pattern which was seen in Fig. 1 results in anomalous behavior of the radio compass due to the appearance of a spurious cone-of-silence and, in extreme cases, to spurious reversals of the compass indication. A properly located compass sense antenna responds only to vertically polarized components of the incident field. In general, there are only two locations on any air frame at which this is exactly true. A usable compass-sense antenna must also have a certain minimum sensitivity. According to present practice, the sense antenna must have an effective height of one-eighth meter and a capacitance of 50 $\mu\mu$f—that is, a sensitivity $h_e C_A$ of 0.063 $\mu\mu$f meters. These values are those that would be measured if the antenna were erected on an extremely large, flat, ground plane. When the antenna is mounted on an aircraft, its capacitance will differ only negligibly from the flat gound plane value. Its effective length and, therefore, its sensitivity will, in general, increase over the flat ground plane values because of the distortion of the incident field caused by the presence of the air frame. The amount of this increase can be described by a *ground plane factor*.

Fig. 3 shows a plot of the measured tilt angle and ground plane factor for a small dipole located at various points along the top and bottom centerline of a DC-6A aircraft. It can be seen from this data that the two locations at which the antenna responds only to vertical

* The author is indebted to the Douglas Aircraft Company for permission to reproduce these data here.

polarization—i.e., the locations where the pattern tilt is zero—occur on the top and bottom centerline just aft of the trailing edge of the wing. At these points the ground plane factor is approximately 2.0. The ground plane factor reaches extremely high values, about 14, at the fore and aft extremities of the aircraft. At these points, however, the tilt angle is close to 90°, so that the antenna behaves as a horizontal dipole.

When the proper location for the compass sense antenna and the corresponding ground plane factor are determined from data like that shown here, the designer has left only the problem of devising a structurally and aerodynamically suitable antenna element that has the required flat ground plane performance. Fixed wire T structures are widely used, and their effective height and capacitance are easily determined. When a cleaner aerodynamic design is desired, it is possible to use a blade-type antenna, such as that sketched in Fig. 4. The effective height and antenna capacitance are plotted in the left-hand figure as a function of the spacing of the bottom edge of the blade section from the aircraft skin. The data show that adequate performance is obtained for ground plane factors of 1.5 or more. The antenna capacitance can be adjusted by means of a trimmer located in the mounting base. A sense antenna of this type has been developed by the Douglas Aircraft Company for use on the DC-6A.

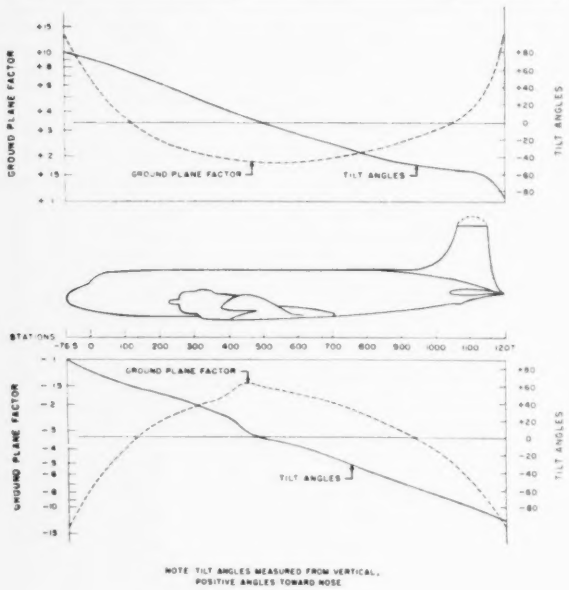

FIG. 3.

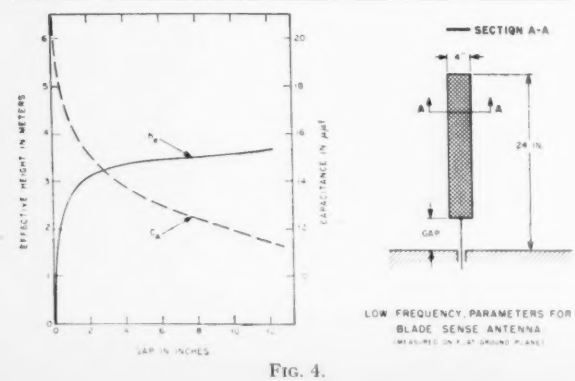

FIG. 4.

If a fully flush design is required, the designer can make use of a cavity type. For any particular ground plane factor and cavity configuration, there is only one cavity size that will simultaneously satisfy both the sensitivity and input capacitance requirements. For a ground plane factor of 2, a satisfactory design based on a cylindrical cavity requires a diameter of 32 in. and a depth of 4 to 6 in., depending on the configuration of the top loading element.

Medium-high-frequency aircraft antennas are used primarily for relatively long-distance air-to-ground communications. There are two basic performance criteria that fix the design limits on antennas for this purpose. The first has to do with radiation patterns. It is obviously desirable that the available power be radiated in those directions in space in which it is most useful. It is not easy to make a specific statement of what directions are "useful." This is because the air crew may, over a sufficiently long period of time, desire to communicate with stations lying at any heading relative to the aircraft and because the varying distances over which communication is desired, taken together with the complex characteristics of the ionosphere, will lead to signal paths at many different vertical angles. The problem is a statistical one, and the answer must be stated in terms of probabilities. A recent study of the high-frequency communications practice of the scheduled commercial carriers shows that the preponderance of all radio contacts are with stations fore and aft of the aircraft, with relatively infrequent contacts to the sides. A study of the distances involved, frequencies employed, and ionosphere conditions encountered indicates that useful signal paths are generally confined to the range of vertical angles between 60° above and 60° below the horizon at 2 mc. and between 20° above and 20° below at 20 mc. Military high-frequency communications requirements differ somewhat from commercial air lines practice, but the conclusions just stated, especially with respect to vertical angles, are still realistic. On this basis we can say that the aircraft antenna design should yield a high *radiation pattern efficiency*, where we define radiation pattern efficiency as the ratio of the power radiated in useful directions to the total power radiated. Fig. 5 shows the radiation pattern efficiencies for a variety of medium-high-frequency antennas on a C-54 as computed from measured radiation patterns. Fig. 5 is for the case when the remote stations are uniformly distributed in azimuth. It is seen from these curves that the fixed-wire antenna is generally the poorest of the antennas studied, while the tail cap is generally the best. The other antennas studied—single and paired wing caps and the loop-excited wing—lie roughly between these extremes.

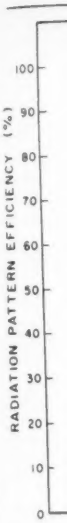

FIG. 5

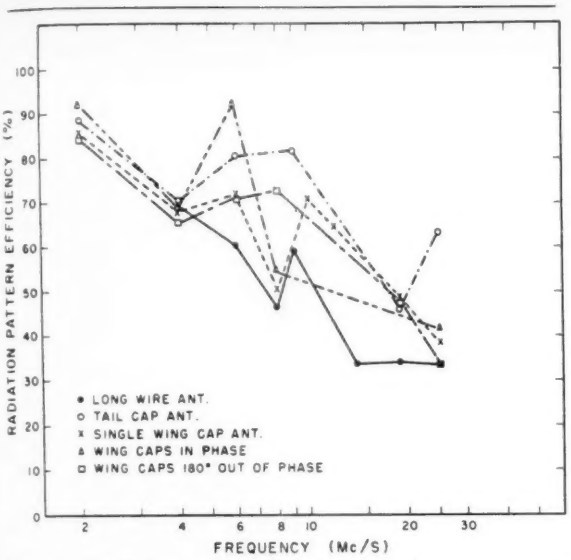
RADIATION PATTERN EFFICIENCY (%)
FREQUENCY (Mc/S)
• LONG WIRE ANT.
○ TAIL CAP ANT.
× SINGLE WING CAP ANT.
▲ WING CAPS IN PHASE
□ WING CAPS 180° OUT OF PHASE

FIG. 5. Radiation pattern efficiency for various antennas on a C-54 aircraft.

The other performance criterion especially important to the choice of a high-frequency antenna design might be termed its *power-transfer efficiency*. Power-transfer efficiency is defined here as the ratio of total power radiated to maximum power available from the transmitter. It is less than 100 per cent because of power lost as heat in the antenna itself, or in its supporting insulators, and to loss in the coils and capacitors of the antenna impedance matching circuit. The product of the radiation-pattern efficiency and the power-transfer efficiency is a good measure of overall antenna system performance, since it is the fraction of the available transmitter power which is useful to communication.

The problem of insulator and conductor losses in the antenna element itself is one about which little of general applicability can be said, excepting the obvious remark that the lowest loss materials available should be used. Studies of specific antenna designs indicate that dielectric loss may account for a high proportion of the input resistance of the antenna at the low end of the frequency range, as much as 80 per cent at 2 mc. in some cases. Certain of the polyester-bonded Fiberglas materials have exceptionally high power factors at 2 mc. per sec. One sample measured in our laboratory had a power factor of 11 per cent at this frequency as compared with 2 per cent for Lucite and 0.3 per cent for Steatite.

The effect on the power-transfer efficiency of loss in the elements of the impedance-matching circuit is easier to present. With practical available components for the element values required, it is largely the finite Q of the coils which determines the power losses in the matching circuit. If certain simplifying assumptions are made, the efficiency of an impedance matching circuit can be estimated directly from the antenna impedance data. Fig. 6 tabulates the calculated power-transfer efficiency of a variety of antenna systems for frequencies of 2 and 5 mc. The antenna impedance data used are for antennas installed on a C-54. These data are based on the assumption that a network using a series inductance and a shunt capacitor is adjusted so as to match the antenna to a 50-ohm impedance level with minimum loss in the circuit. It is further assumed that the coil has a Q of 100 and the capacitor has a dissipation factor of 0.001. The results shown demonstrate the obvious fact that the further the antenna impedance is from a match to 50 ohms, the lower the power-transfer efficiency that will be obtained. In particular, the lowest operating frequencies, where the antenna impedance combines low input resistance with high input reactance, are inherently the most difficult at which to achieve good power-transfer efficiency.

It is apparent from these data that wing cap and tail cap offer substantial advantages over wire antennas in power-transfer efficiency. We have seen from previous figures that cap-type antennas are superior to wire antennas in radiation-pattern efficiency also. Cap antennas do suffer from the major disadvantage that their design requires that primary structure of the air frame must be replaced with an insulating material. If this price must be paid for an adequate long-range communications system, and the state of the art offers no immediate alternative, then the design problem is clear: The least expensive compromise between electrical performance and structural complication must be found. The resolution of this problem demands close cooperation between the antenna designer and those responsible for structural designs. Fig. 7 shows a number of possible cap antenna configurations on a Constellation aircraft, together with the relative 2 mc. input conductance and the orientation of the axis of the nulls of the radiation patterns, which at this frequency are essentially figures-of-eight. All of the configurations shown radiate essentially horizontally polarized fields. The input conductances are all shown relative to that of a 4-ft. wing cap which is taken as 100. This is done because experience has shown that a wing cap of this size provides good performance.* These data do not tell the whole story, of course. Some of the configurations that look acceptable at 2 mc. turn out to have poor impedance characteristics and, therefore poor power-transfer efficiency at higher frequencies. It is true, however, that configurations that are poor at 2 mc. will generally be unacceptable as high-frequency antennas.

When the operating wave length is small compared with the dimensions of the aircraft structure, it becomes relatively easy to design an antenna that has acceptable bandwidth and impedance characteristics. In some applications—for example, the glide slope receiver and the radio altimeter—"packaged" antennas are available which can be incorporated into new aircraft designs virtually without change. There is a continuing trend toward the development of such packages for an increasing number of very-high-frequency and ultra-high-

* The author is indebted to the Lockheed Aircraft Corporation for permission to publish these data.

frequency antenna systems. Fig. 8 illustrates some of the significant physical characteristics of certain of these designs. The three basic antenna configurations considered here are various forms of slot radiators. The right-hand column refers to applications of the annular slot. This structure can be viewed as a degenerate form of the stub antenna, and it is useful where the application calls for an omnidirectional pattern, polarized perpendicularly to the metal surface containing the slot. Three applications are apparent, very-high-frequency and ultra-high-frequency communications and distance-measuring equipment. All of these systems are vertically polarized, so that the annular slot, if used, must be located on a reasonably flat, horizontal portion of the skin of the air frame. The low-frequency limit of the pass band of the annular slot radiator occurs approximately when its diameter is a half wave length. At very high frequencies, then, the slot is necessarily large, over 4 ft. in diameter. At ultra high frequencies the diameter required is more modest, about 20 in., but the depth of the backing cavity required may lead to difficulties in installation on air frames having highly stressed skin covering or where cabin pressurization is required.

The rectangular cavity, radiating from its long, narrow side, has an inherent directive pattern, resembling that of a loop in a plane perpendicular to the longer dimensions of the slot. This type of directivity makes this configuration eminently suited to glide slope reception if it can be located in a forward-looking surface, preferably the nose. The narrow bandwidth required here, coupled with the relatively high operating frequency, permits the use of an antenna sufficiently small to permit its application to most aircraft. This antenna does not produce enough directive gain to make it wholly satisfactory for radio altimeter applications, although its bandwidth is adequate. It is possible to use pairs of the antennas, mounted with their long axes parallel, separated by approximately a half wave length, and excited in phase, to achieve adequate gain. This approach complicates the problem of structural design, however, and may further restrict the choice of location on the air frame.

The other form of rectangular cavity, in which one of the large faces of the cavity is opened as a radiator, is especially useful when horizontally polarized operation

ANTENNA TYPE	IMPEDANCE 2Mcs	IMPEDANCE 5Mcs	EFFICIENCY 2Mcs	EFFICIENCY 5Mcs
65' FIXED WIRE (OPEN)	1.2 − j430Ω	10.6 + j460Ω	20%	77%
65' FIXED WIRE (SHORTED)	10.3 + j900	11.5 − j550	59	67
2' WING CAP	7 − j1200	23 − j460	39	83
7' TAIL CAP	7 − j425	7.5 − j155	62	82

FIG. 6. Comparative power-transfer efficiencies for four antenna types on a C-54 aircraft. Assumes L-section matching network with Q = 100 for series coil, D = 0.001 for shunt capacitor.

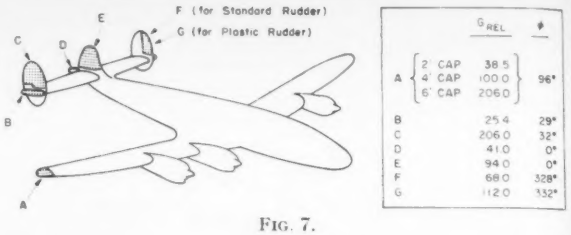

FIG. 7.

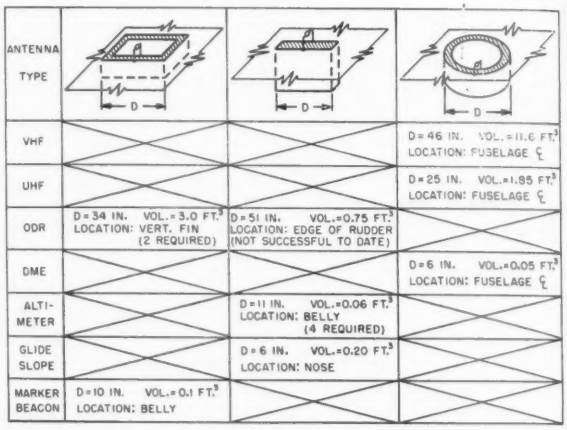

FIG. 8.

is required. The Alford island antenna, the Boeing Double-E omnidirectional range antenna, and the "bathtub" marker beacon antenna are all of this type. If an omnidirectional pattern is required, it is necessary to use two radiators, mounted back-to-back on either side of a vertical portion of the aircraft. Two locations are possible: the vertical fin or the sides of the nose. The latter may lead to difficulties in obtaining an azimuthal pattern free from deep nulls if the wing is strongly illuminated or if the two antenna elements are separated by too great an electrical distance Location in the vertical fin may not be possible if the thickness of the fin is not adequate to permit the cavity depth required for adequate bandwidth.

Various other configurations of very-high-frequency antennas are in wide use, many of them designs specially tailored to meet the restrictions imposed on size and location in particular aircraft. Because it offers a relatively unobstructed line-of-sight view, the fin tip is an especially popular location for very-high-frequency and ultra-high-frequency antennas. All ultra-high-frequency and very-high-frequency antennas for aircraft intended for applications requiring omnidirectional coverage are inherently limited by the quasi-optical behavior of radio waves at these frequencies. The most serious difficulties are due to shadowing. The fin tip is not exempted from this limitation. Fig. 9 shows the shadow cast on the earth by a typical aircraft for an antenna located on the fin tip. The aircraft involved is the C-124, which has an exceptionally tall vertical fin, so that the results shown here can be taken to be about the best that can ever be expected. The figure shows the shape and size of the shadowed area

on the earth when the aircraft is flying straight and level at an altitude of 15,000 ft. The shadowed region ahead of the nose extends forward of the aircraft over 10 miles. The actual situation is even worse. Because of interference between the direct ray and rays reflected from the top of the fuselage and the wings, the forward lobe is tilted above the edge of the shadow, so that coverage on the ground may be inadequate at even larger distances than would be predicted on the basis of the optical shadow alone.

There is no cure for this difficulty which has proved acceptable in practice. It is obvious that, whatever location is chosen for the radiating element, the air frame will shadow a large portion of the region in which communication may be required. The simultaneous use of multiple antennas is not practical unless some diversity system is employed to avoid destructive interference between their individual radiation patterns. Simple switching may be adequate for reception where the switch position has an obvious effect on communication, but no information is available to the pilot to tell him which switch position to use when transmitting. The solution to these difficulties is one of the most serious problems facing the aircraft antenna designer today. It will not be easy, and it is virtually impossible to visualize a method that will not further increase the space, weight, and location demands of the antenna system.

In summary, design methods for satisfactory antennas for low-frequency and high-frequency requirements are available, but many very-high-frequency and ultra-high-frequency requirements are beyond the present state of the art. Even when designs are available, problems arise because acceptable antenna performance can be obtained only when antennas of adequate size and proper shape can be placed in the correct location on the air frame. The degree to which these parameters can be compromised without deteriorating the antenna performance to the point where it is no longer acceptable is at best small. Solution of the ultra-high-frequency problem is not yet in sight, but it will inevitably result in even greater demands for increased space and weight and for additional locations on the air frame. It is vitally important that the space, location, and weight demands inherent to the design of successful antennas for airborne equipment should receive the careful attention of the air-frame designers as early as possible in the development of a new aircraft. This responsibility inevitably rests on the aircraft antenna engineer. He must marshal his facts and present his case well, lest he find himself in the unhappy position of having to violate the fundamental laws of physics in order to do his job. This sort of crime, at least, doesn't pay.

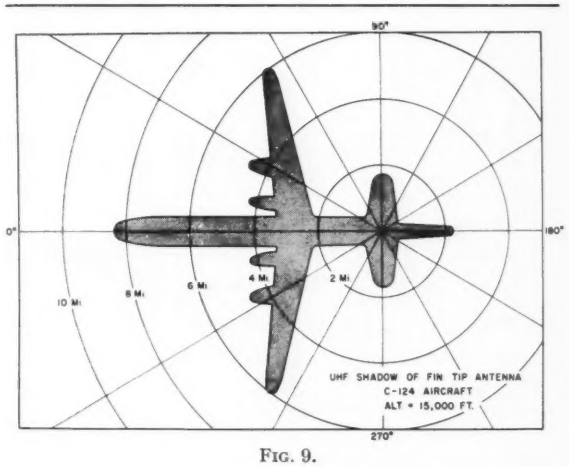

FIG. 9.

Present Status of Transistor Development

(*Continued from page 45*)

is involved; that much more lies ahead than in the past; that, indeed, we may be entering a new field of technology—i.e., "transistor electronics."

ACKNOWLEDGMENTS

It was stated earlier that these advances in the development of transistors have resulted from improved understanding, materials, and processes. These improvements have been made through the efforts of a large number of workers in physical research, chemical, and metallurgical research and transistor development. In reality, these colleagues are the authors of this paper; and it is to them the writer owes full and appreciative credit for the material that has made possible this report of progress in transistor electronics.

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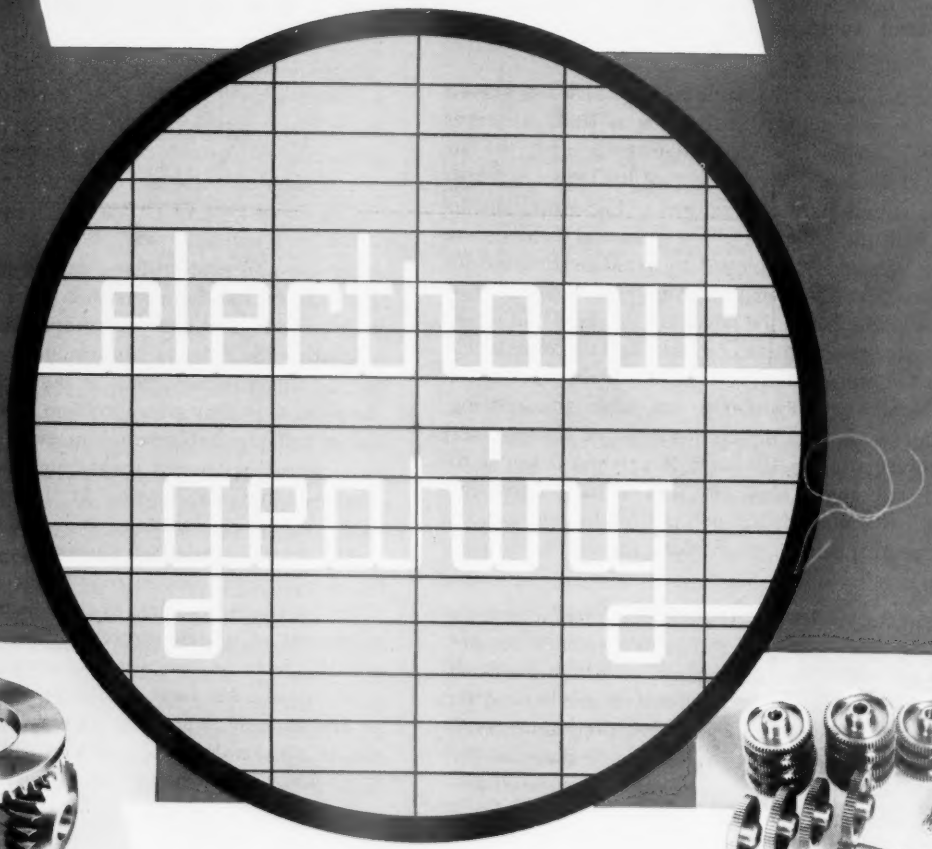
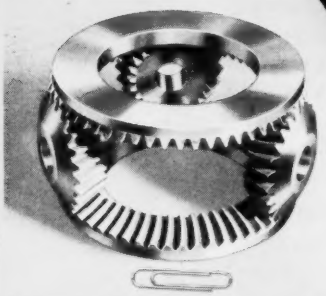
ELECTRONIC
GEARS and GEAR DRIVES





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I.A.S. Previews

Summaries of Current Papers Accepted for I.A.S. Publications

Buckling of Sandwich Cylinders Under Bending and Combined Bending and Axial Compression

By

Chi-Teh Wang and D. P. Sullivan

New York University

A theoretical investigation of the buckling of sandwich cylinders under bending and combined bending and compression is carried out. By solving Donnell's equation modified to include the effects of transverse shear using Galerkin's method, the buckling load is determined. For a sandwich cylinder with a weak core, it is found that buckling occurs when the maximum compressive stress in the cylinder reaches the buckling stress of the cylinder under axial compression alone.

The Impingement of Spherical Water Droplets on a Wedge at Supersonic Speeds in Air

By

Myron Tribus and Armand Guibert

University of Michigan and University of California at Los Angeles, Respectively

The water drop interception characteristics of a wedge in a supersonic flow field are investigated analytically for the case of flows in which the shock wave is not detached. The results indicate that, contrary to the subsonic flow cases considered previously, there is no limiting position on the wedge beyond which the droplets cease to strike, but rather icing may occur along the entire wedge surface.

General Reverse Flow and Variational Theorems in Lifting-Surface Theory

By

A. H. Flax

Cornell Aeronautical Laboratory, Inc.

By introducing the integral equation and auxiliary conditions adjoint to the integral equation and Kutta condition of lifting-surface theory, certain general theorems in lifting-surface theory are derived. It is shown that the adjoint to the integral equation of a lifting surface is the integral equation for the same surface in reverse flow and that, to satisfy the requirements on such an adjoint, the Kutta condition must also be imposed on the solutions of the equation for the surface in reverse flow. The adjoint relationship between wings in direct and reverse flow is shown to lead to a general class of relationships between the characteristics of wings in direct and reverse flow for either subsonic or supersonic speeds. Also, it is shown that the total lift, pitching moment, and rolling moment on a wing of any camber and twist may be expressed as a closed-form integral over certain pressure distributions of the same wing in reverse flow. These distributions correspond to the case of the wing in reverse flow at constant angle of attack, pitching with uniform velocity, and rolling with uniform velocity. The formulas may be regarded as generalizations of the Munk two-dimensional airfoil integral relations to which they reduce for infinite aspect ratio. Finally, an adjoint variational principle for lifting surface in subsonic flow is obtained. In combination with the form of the Rayleigh-Ritz method, this is shown to lead to suitable methods for approximate solution of lifting-surface problems. On the basis of the variational principle, certain apparently arbitrary or intuitive steps in the approximate theories of Prandtl, Weissinger, Reissner, and Lawrence are shown to be logical applications of the same method.

Dynamic Stability of a Missile in Rolling Flight

By

Ray E. Bolz

Case Institute of Technology

The paper sets down the equations of motion for a symmetric rolling missile with respect to axes attached to the missile. The missile may be jet (or rocket) propelled or coasting under accelerating or decelerating conditions, respectively, wherein the variable rolling velocity is derived from intentionally or unintentionally "canted" fins and/or wings.

The equations contain a force and moment system that includes, in addition to the usual, those due to magnus effects, misaligned surfaces, canted surfaces, jet misalignment, and the linear accelerations in the plane normal to the missile axis.

The results present general stability criteria for a rolling missile which are summarized in the Discussion of Stability.

Please do not order Preprints of these papers at this time.
See page 126 for Preprints that are immediately available.

Diffuser Efficiency of Free-Jet Supersonic Wind Tunnels at Variable Test Chamber Pressure

By

Rudolf Hermann

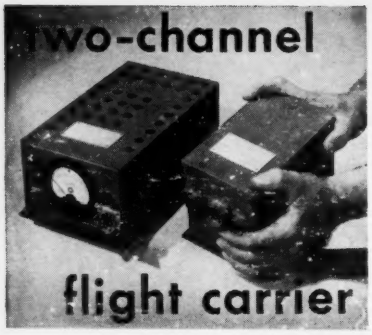
University of Minnesota

The flow process occurring in the diffuser of a supersonic wind tunnel with free jet and its efficiency have been previously investigated by the author (see A. F. Tech. Report No. 6334, December, 1950) for the special case, where the pressure in the test chamber surrounding the jet is equal to the pressure in the exit cross section of the Laval nozzle.

The present analysis deals with the general case, where the test chamber pressure is different from the nozzle exit pressure. By using the basic equations of continuity, energy, and momentum flow through a control surface, an exact solution for one-dimensional, nonviscous, steady flow is obtained.

One of the basic results is that the flow—after the transformation process in the diffuser is completed—is subsonic if the test chamber pressure is above, equal to, or below the nozzle exit pressure. A supersonic flow is possible, too, if the test chamber pressure is smaller than a certain finite limit below the equilibrium.

The results are presented in eight graphs over a Mach Number range from



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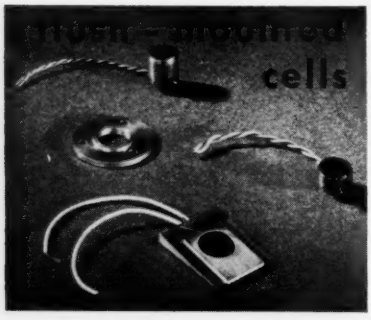

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1 to 10, showing velocity and pressure after the transformation, diffuser efficiency, total pressure ratio, and diffuser throat area at variable chamber pressure. The analysis shows also, for the first time, the exact mechanism of test chamber pressure control for the subsonic solution by means of an adjustable diffuser throat and the quantitative description of a "slow starting" process of the tunnel.

Downwash Behind a Two-Dimensional Wing Oscillating in Plunging Motion

By

Ellis Lapin, R. Crookshanks, and H. F. Hunter

Douglas Aircraft Company, Inc.

A solution in closed form is found for the downwash behind a two-dimensional wing oscillating sinusoidally in plunging motion. The polar representation of the downwash at a given distance behind the wing is a divergent spiral. At large distances behind the wing, the downwash variation with distance is sinusoidal.

An Investigation of the Effect of a Varying Tip Weight Distribution on the Flutter Characteristics of a Straight Wing

By

William H. Gayman

Northrop Aircraft, Inc.

Experimental and theoretical investigations into the antisymmetric flutter characteristics of a straight wing having a number of tip-pod mass, size, and shape configurations are summarized. The experimental phase, conducted with a low-speed flutter model of the U.S. Air Force's Northrop Scorpion F-89 wing, is discussed from the standpoint of a design development study. Model design features, testing techniques, and test results are described, with emphasis on an observed need for considering small variations of mass distribution within a pod having expendable content.

Methods and results of theoretical flutter analyses of several tested pod configurations are discussed. Computations from parallel analyses using different assumptions of pod aerodynamic effectiveness are compared with test data.

It is concluded from these investigations that the aerodynamically effective tip pod may be small in comparison with the pod geometric plan form but, further, that an accurate representation of this effective tip pod may be essential to a successful flutter analysis. It is also indicated that analyses of wing-and-pod configurations having the pod center of gravity on or near the wing elastic axis are more adversely affected by errors in pod aerodynamic representation than are those analyses applying to cases of large pod overbalance.

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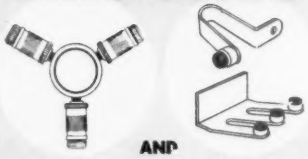

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Free-Flight Air-Drag Measurement Techniques

By

A. B. J. Clark, F. T. Harris, and R. E. Roberson

Naval Research Laboratory

Using the ballistic pendulum air-drag technique with pendulums of several different lengths, the air-drag coefficient C_D has been determined for Cal. 0.50 spheres in the region of Mach Numbers 1.4 to 5.4. A conventionally suspended pendulum with a period of 3.2 sec. was used to obtain most of the data; the values of C_D so obtained were consistently about 6 per cent low. It was suspected that the time of momentum transfer covered too great a fraction of the pendulum period. For this reason, pendulums having seismographic suspensions with periods from 17.5 to 30 sec. were installed. After correction for end effects, the values of C_D then obtained agreed closely with the results of other methods. The influence of baffle-hole size and correction for end effects are discussed.

Attention Members!

All members of the Institute are invited to submit material concerning their activities for publication in the "News of Members" columns of the *Aeronautical Engineering Review*. Responsibility for new developments, awards or honors received, and appointments to new or additional positions are some of the items that your editors believe are of interest to other I.A.S. Members. A brief letter or postal card giving exact details will be sufficient. Photographs accompanying news items will be welcomed and will be used where practicable.

Items submitted will be considered on the basis of their timeliness and general interest. Correspondence should be addressed to the News Editor, *Aeronautical Engineering Review*, 2 East 64th Street, New York 21, N.Y.

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I.A.S. News (Continued from page 23)

Junior Engineer, Clarence M. Blair Associates.

Stephen R. Matos (M), Assistant Project Engineer, Special Devices Division, Austin Company. Formerly, Aircraft Stress Analyst, Gassner Aircraft Engineering Company.

John F. McCarthy, Jr. (T.M.), now Research Engineer, Aero-Elastic and Structures Research, Massachusetts Institute of Technology.

Kenneth O. McRee (M.), now Commander, U.S. Navy. Formerly, Aircraft Designer, McDonnell Aircraft Corporation.

K. J. Mosbacher, Jr. (T.M.), Supervisor of Lockheed Contracts, Aircraft Gas Turbine Division, General Electric Company. Formerly, Contracts Officer, George O. Roper Corporation.

Lieutenant Thomas E. Neal, U.S.N. (T.M.), Naval Air Station, Grosse Ile, Mich. Formerly, Experimental Stress Engineer, Continental Aviation and Engineering Corporation.

James A. Neilson, Jr. (T.M.), now Stress Technologist, Fairchild Aircraft Division, Fairchild Engine and Airplane Corporation.

Marvin L. Nelson (M.), Works Manager, Wakonda Works, Solar Aircraft Company, Des Moines, Iowa. Formerly, Chief Engineer, Grand Avenue Works, Solar Aircraft Company, Des Moines.

Second Lieutenant Peter J. Poletti (T.M.), H.Q., Army Security Agency, 8600 A.A.U., The Pentagon, Washington, D.C. Formerly, Design Engineer, Grumman Aircraft Engineering Corporation.

Alan Pope (M.), Supervisor, Wind Tunnel Section, Aerodynamics Division, The Sandia Corporation. Formerly, Aerodynamicist, The Sandia Corporation.

G. V. R. Rao (M.), Technical Engineer, Aircraft Gas Turbine Division, General Electric Company. Formerly, Assistant Professor, Indian Institute of Science, Bangalore, India.

Major Calvin D. Reifsteck, U.S.A.F. (T.M.), Student Officer, U.S.A.F. Course: Management of Research and Development Installations and Candidate for M.B.A. Degree, University of Chicago. Formerly, Project Engineer on Aircraft Gas Turbine Engines, Power Plant Laboratory, Engineering Division, Wright-Patterson Air Force Base, Ohio.

Wilhelm F. Schult (M.), Stress Analyst, Harper Engineering Company. Formerly, Stress Analyst and Engineer Designer "A," Aero Cal. Engineers, Inc.

Alvin M. Schultz (T.M.), now Project Engineer, Aircraft Division, The White Motor Company.

Maurice S. Sevelson (T.M.), Group Engineer, Texas Engineering and Manufacturing Company. Formerly, with Fletcher Aviation Corporation.

Robert H. Shatz (M.), Department Head, Special Projects, Cornell Aeronautical Laboratory, Inc. Formerly, Assistant Department Head, Special Projects, C.A.L.

Karl D. Swartzel (M.), Staff Scientist, Director's Office, Cornell Aeronautical Laboratory, Inc. Formerly, Head, Physics Department, C.A.L.

Robert C. Tetens (T.M.), Stress Section Head, Arizona Division, Goodyear Aircraft Corporation. Formerly, Design Engineer, McDonnell Aircraft Corporation.

Charles R. Weiss (T.M.), Designer, Goodyear Aircraft Company. Formerly, Designer, Griscom Russell Company.

R. E. Whiteway (T.M.), Reservations, Agent, Chicago Office, American Airlines System. Formerly, Technical Writer, Fort Worth Division, Consolidated Vultee Aircraft Corporation.

Victor Zakkay (T.M.), Research Assistant, Polytechnic Institute of Brooklyn. Formerly, Student, Brooklyn Polytechnic.

Corporate Member News

• **Aeroproducts Division, General Motors Corporation**. . .According to a report, Aeroproducts is supplying propellers for all of the four types of turboprop aircraft now flying in the United States. These are: the Convair XP5Y-1 and Turboliner, the Douglas A2D attack bomber, and the North American XA2J-1 Navy bomber.

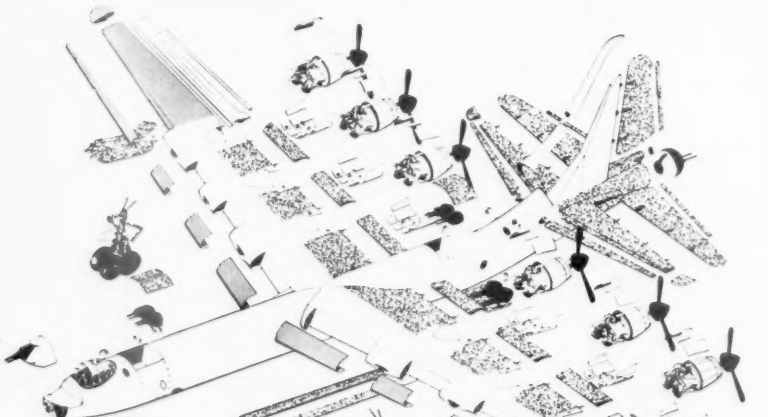
• **Aeroquip Corporation**. . .Many of the company's aircraft products are described in Bulletin No. 223, now available gratis.

• **AiResearch Manufacturing Company, Division of The Garrett Corporation**. . . Claude N. Monson was elected a Vice-President and Manager of AiResearch.

• **Aluminum Company of America**. . .A "stretching" machine for straightening aluminum extruded parts, exerting 3,000,000 lbs. total pull, has been ordered for Alcoa's Lafayette (Ind.) extrusion works. It will be installed in about a year. This new stretcher will take care of parts extruded by Alcoa's new 13,200-ton extrusion press at Lafayette.

• **American Airlines System**. . .Vice-President O. M. Mosier, A.M.I.A.S., now directs and coordinates American's Operations, Maintenance & Supply, and Engineering departments. Reporting to Mr. Mosier under the scope of his new duties, which he assumed on March 15, are: L. G. Fritz, M.I.A.S., Vice-President—Operations; G. J. Brandewiede, M.I.A.S., Vice-President—Maintenance & Supply; and M. G. (Dan) Beard, M.I.A.S., Chief Engineer. Additional changes to effect a closer coordination of the operating departments include the following: C. W. Jacob, Vice-President, has taken over the duties formerly performed by Mr. Mosier, and Walter H. Johnson, Jr., is directing the Properties and State Affairs departments, reporting to Mr. Jacob. Mr. Johnson is continuing in his capacity as Secretary of the corporation.

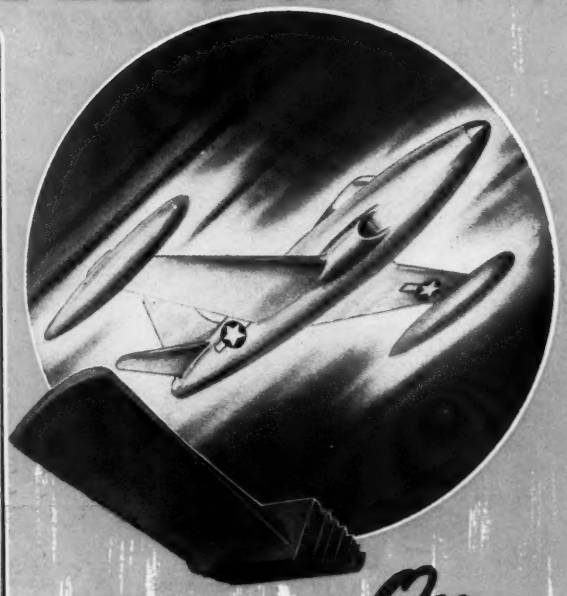
• **American Helicopter Company, Inc.**. . . Now under development is a small helicopter of 700 lbs. gross weight. Desig-



PRIME AND SUBCONTRACTING

The legend in the lower left corner of this exploded view of Consolidated Vultee Aircraft Corporation's B-36 bomber shows the origin of many of its parts and components. There are, of course, hundreds of purchased items, most of which are installed in the interior, which are not indicated in this sketch.

when the HEAT is on. . .



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nated the XH-26, it can be parachuted from transport planes into combat areas or used on observation missions. When prepared for dropping, the helicopter will weigh under 300 lbs. and can be collapsed into a 5- by 5- by 14-ft. container. The XH-26 is powered by two 16-lb. pulse-jet engines, has a top speed of 80 m.p.h., and can fly for 90 min. without refueling.

• **Boeing Airplane Company**. . .The Department of Defense recently announced the awarding of an Air Force contract to Boeing "for an engineering study of nuclear power plants to aircraft." The contract, under which Boeing is working in close cooperation with Pratt & Whitney Aircraft Division of United Aircraft Corporation, was awarded last year.

• **Canadair, Ltd**. . .The company has been licensed by Douglas Aircraft Company to manufacture the DC-6, DC-6A, and DC-6B.

• **Cessna Aircraft Company**. . .Final steps were completed on February 25 by Cessna for the acquisition of Seibel Helicopter Company, Wichita, Kan. Charles M. Seibel, formerly Head of Seibel Helicopters, was retained by Cessna as Chief Engineer of the Helicopter Division.

• **Consolidated Vultee Aircraft Corporation**. . .The Charactron, a special type of cathode-ray tube developed by Convair under license from the patents of Joseph T. McNaney, Senior Electronic Engineer at Convair, uses a beam-forming matrix that is located between the electron gun and the fluorescent screen and which contains character-shaped openings. This new tube can display messages transmitted by high-speed communications systems or can record the output of high-speed analog or digital computers. The Charactron, which combines electronics and dry photographic techniques, can record intelligence at rates as high as 10,000 characters per second. . .The U.S. Air Force recently revealed in a guarded announcement that Convair has been awarded a contract for prototype production of a new high-performance interceptor aircraft. . .A $200,000 contract to develop use of titanium alloy in the manufacture of jet-pod parts was awarded to Convair by the U.S.A.F. . . .The construction of additional facilities at the Fort Worth Division, involving an outlay of about $3,000,000, has been announced. . . At the March 3 meeting of Convair's Board of Directors, Gen. Joseph T. McNarney, U.S.A.F. (Ret.), was elected President of the corporation, succeeding LaMotte T. Cohu who was elected Vice-Chairman of the Board of Directors. Both officers assumed their new posts on April 1. General McNarney retired from the Air Force on January 31, 1952, after 35 years of military service.

• **Cornell Aeronautical Laboratory, Inc**. . . A new research division, known as the Industrial Division, was recently formed at Cornell Aeronautical Laboratory. The establishment of this new division is a move to permit more concentration by Cornell in research fields useful to industry. This division will lay more emphasis upon exploratory and fundamental research than was possible under the previous organizational arrangement de-

voted as it was to intensive military research and development. The Industrial Division will be headed by Edward R. Dye, M.I.A.S. In order to maintain fulfillment of current development needs and to allow for increased exploratory research, the Development Division has been altered to include three major technical branches plus two shops—experimental and model. The new branches of the Development Division are Electrical Engineering, Weapons Engineering, and Mechanical Engineering. Dr. Mark Foster, M.I.A.S., will head this division.

• **Eclipse-Pioneer Division, Bendix Aviation Corporation**. . .Two new altimeters designed to operate between 150,000 ft. and 300,000 ft. and between 300,000 ft. and 500,000 ft. are being developed by the U.S.A.F.'s Air Research and Development Command. Two experimental models of each altimeter have been built according to U.S.A.F. specifications by Eclipse-Pioneer and are currently undergoing tests at the National Bureau of Standards. The altimeter designed for the lower altitude (150,000–300,000 ft.) is basically a Pirani-type gage. It consists of a glass tube, which continuously samples the atmospheric air, and a cathode element, which is heated by an electrical current. The other altimeter for the higher altitude range (300,000–500,000 ft.) is basically an ionization-type gage and consists of three elements—i.e., a plate, a grid, and a filament.

• **Elastic Stop Nut Corporation of America**. . .The stockholders of Elastic Stop Nut and American Gas Accumulator Company, of Elizabeth, N.J., have agreed to a merger of the two companies. Under this agreement, American Gas Accumulator will operate as a division of Elastic with the present AGA management. The AGA Division manufactures aviation ground lighting equipment, automatic aids to marine navigation, "Agastat" time-relays used in electrically controlled circuits, and "Stimsonite" traffic reflector signs and signals.

• **Electrol Incorporated**. . .The following names of newly elected Vice-Presidents of the corporation were recently announced: Howard B. Smith, Sales Manager; Edmund D. Holland, Manager of Development and Engineering; George D. Logan, Plant Manager; and Rudolph Ratschitzky, Secretary and Treasurer.

• **Ethyl Corporation**. . .The new manufacturing plant, under construction in Pasadena, Tex., is scheduled to go into production late this spring. . .Vice-Presidents Joseph A. Costello, B. Bynum Turner, and Sanford M. Wagner have been elected to the Board of Directors. Mr. Costello is responsible for the coordination and planning of the corporation's activities; Mr. Turner heads Research and Engineering; and Mr. Wagner is in charge of Sales.

• **General Electric Company**. . .On February 25, de Havilland Engine Company, Ltd., of Great Britain, and General Electric, through its overseas affiliates, International General Electric Company, jointly announced the completion of an intercompany agreement, i.e.—"a full interchange of knowledge and experience,

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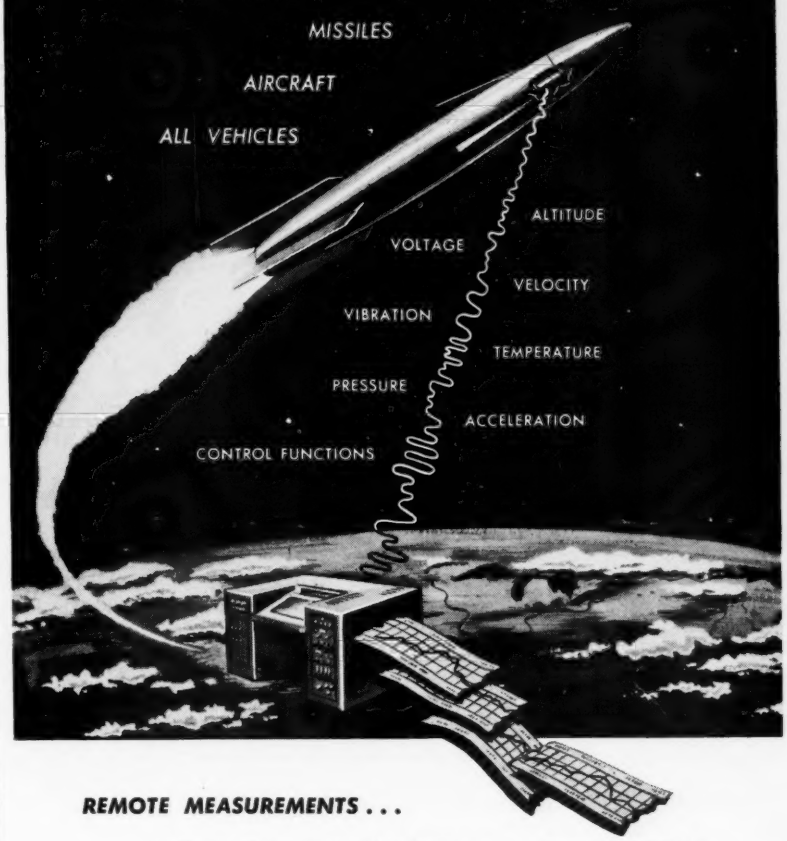

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These are but a few examples of how ASCOP has applied basic scientific principles to new devices. If understanding and imagination is required for the solution of your special electronic or electro-mechanical problem, or if you desire improvement of any existing solution, your inquiries are invited.

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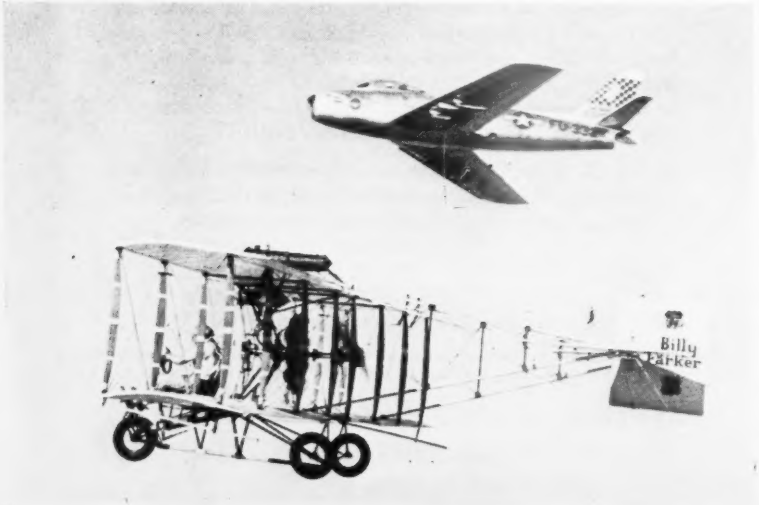
both current and future, in the field of gas turbines for aircraft, with the exception of the aircraft nuclear propulsion." This arrangement, which was approved by the U.S. Government and the British Ministry of Supply, provides for the exchange of key technicians between de Havilland Engine Company and G-E's Aircraft Gas Turbine Division. Currently in production at de Havilland are two centrifugal-flow turbojet engines—the Goblin 35 rated at 3,500 lbs. static thrust and the Ghost 50 rated at 5,000 lbs. static thrust. Among the projects now either in production or under development at G-E are various axial-flow turbojets, as the J-47 series, the J-53, and the J-73 (formerly the J-47-GE-21). . .An automatic pilot, designated the G-3, has been developed by the Aeronautic and Ordnance Systems Division in cooperation with the U.S.N. Bureau of Aeronautics. This new autopilot, which was designed to relieve the Navy fliers of 90 per cent of their "stick and rudder" work, controls the plane at near-sonic speeds and can be used in such maneuvers as gunnery runs on enemy aircraft. The G-3 is said to return the airplane to level flight from any attitude up to 75° in pitch or bank. The G-3 system consists of a G-2 compass, a vertical gyro, and a rate gyro that feed electric signals into an amplifier. The amplified signals are then applied to one or more of three motor-driven actuators that move the airplane's control surfaces. It was designed for use in high-speed Navy jet fighters. . . A new method has been developed by G-E's Thomsom Laboratory for the Aircraft Gas Turbine Division which permits the blades on the stator portion of a jet-engine compressor to be fabricated rather than forged. After a series of tests were run on the fabricated blade and no undersirable conditions or signs of future failure were noted by the testing engineers, the U.S. Air Force approved the substitution of fabricated stator blades for the forged ones in the G-E J-47-GE-23 turbojet now going into large-scale production for the Boeing B-47 Stratojet. This fabrication process, which, it is said, will make possible a 55 per cent reduction in the cost of manufacturing stator blades, is being made available, through the U.S.A.F., to other American turbojet manufacturers. . .A company-financed expenditure of $30,000,000 has been announced for the construction of an aircraft gas turbine research laboratory and associated development facilities at Lockland, Ohio. The new installation will stress development; however, it will of necessity also engage in basic research. The laboratory, which will occupy a 5-acre tract of land, will constitute a large portion of the jet-engine center at Lockland, when completed. Dedication ceremonies of the jet-engine center took place on March 18 and 19 in commemoration of "the fastest 10 years in aviation history.". . .The aviation equipment business has been expanded to include a new operation for the design, manufacture, and sale of turbine-driven accessories for jet engines and aircraft. Included among the products that are now being produced or developed by this new business, designated Accessory Turbine, are turbosuperchargers and impellers, jet engine starters, turbine-driven fuel pumps, and air-turbine drives for alternators and hydraulic pumps. Headquarters for commercial, engineering, and manufacturing activities are at G-E's River Works Plant at Lynn, Mass.. . .William W. Trench has retired from his post as Secretary of G-E which he has held for the past 24 years.

1912–1952 OR PUSHER VS. JET

Caught by the camera at the instant of passing a 1912 model pusher biplane, a late model F-86 Sabre, manufactured by North American Aviation, Inc., graphically demonstrates 40 years of progress in aircraft design and construction. The 1912 pusher is powered by an 80-hp. engine and cruises at 60 m.p.h. It was built by Billy Parker, Manager—Aviation Division, Phillips Petroleum Company, who is shown at the controls. The Sabre, powered by a General Electric J-47 turbojet engine rated at 5,200 lbs. thrust, holds the official world's speed record of 670 m.p.h. The 1912 Pusher and the Sabre weigh 1,075 lbs. and 13,715 lbs., respectively. The Phillips Petroleum Company's trade mark, the "Phillips 66" shield, can be seen affixed to the rudder of the old biplane.



• **The B. F. Goodrich Company**. . .Patents covering the basic features of tubeless tires have been issued to the company. The features covered by the patents are the tire's air-tight lining, the sealing ridges that lock the tire to the wheel, and the sealant that heals punctures while the tires are in actual service.

• **Grumman Aircraft Engineering Corporation**. . .The F9F-6 Cougar is now coming off the Grumman production lines. This swept-wing successor to the earlier Panther is powered by a Pratt & Whitney turbojet engine and is in the "over 600 m.p.h." category.

• **Hamilton Standard Division, United Aircraft Corporation**. . .A recent announcement issued jointly by Hamilton Standard and Bart Laboratories Company, Inc., told of the development of a process for the nickel coating of aluminum. A synthetic rubber compound developed by Hamilton Standard is used to establish a bond between the two metals. This plating process has been named "Alni-Clad."

• **Jack & Heintz, Inc.**. . .An environment free alternator cooled by water vaporization has been developed by Jack & Heintz in connection with North American Aviation's guided missile research program. The G75 Alternator, said to be the first successful vaporization-cooled environment-free alternator in the industry, reportedly maintains satisfactory cooling while operating in extreme conditions of temperature and altitude. By utilizing the vaporization cooling system, the G75 Alternator and its water supply are thermally isolated from environment. The alternator, 93 per cent efficient, requires $3\frac{1}{2}$ lbs. of water an hour at rated load. However, its operation is limited to a cycle that depends on the capacity of the coolant reservoir. Size of the reservoir is, of course, limited by weight and space available to the aircraft. In operation, coolant from the reservoir is injected into the alternator's hollow shaft under pressure. Centrifugal force propels the water through four ports in spray form and scatters it on the internal surfaces of the machine. As it picks up heat from these surfaces, the water vaporizes to become the coolant. Resultant steam is exhausted through a port. Water-inlet flow is regulated automatically by a special J&H valve that is controlled by a temperature-sensing element in the alternator. The three-phase, 400-cycle, 12,000-r.p.m. unit is rated at 12 kva., but it can deliver 16 kva. and maintain satisfactory cooling. Field power for the machine is taken from the output leads through slip rings and brushes, passed through the rectifier bank and magnetic amplifier of a specially designed exciter-voltage regulator, and then to the field. The J&H-developed exciter-voltage regulator used with the G75 is of the magnetic-amplifier type. The G-75 regulator, which has no moving parts, is said to provide excellent response time and to be adaptable for either blast or vaporization cooling. Commutation problems are minimized in the alternator since the steam atmosphere acts as a lubricant between the

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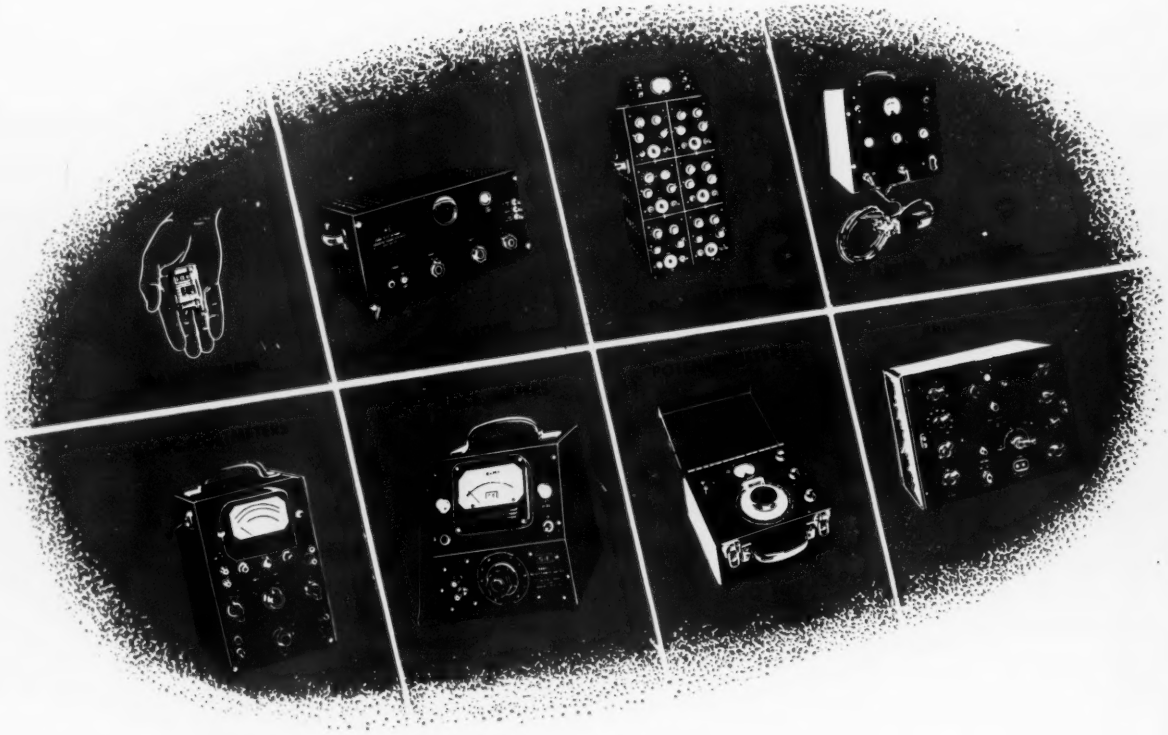

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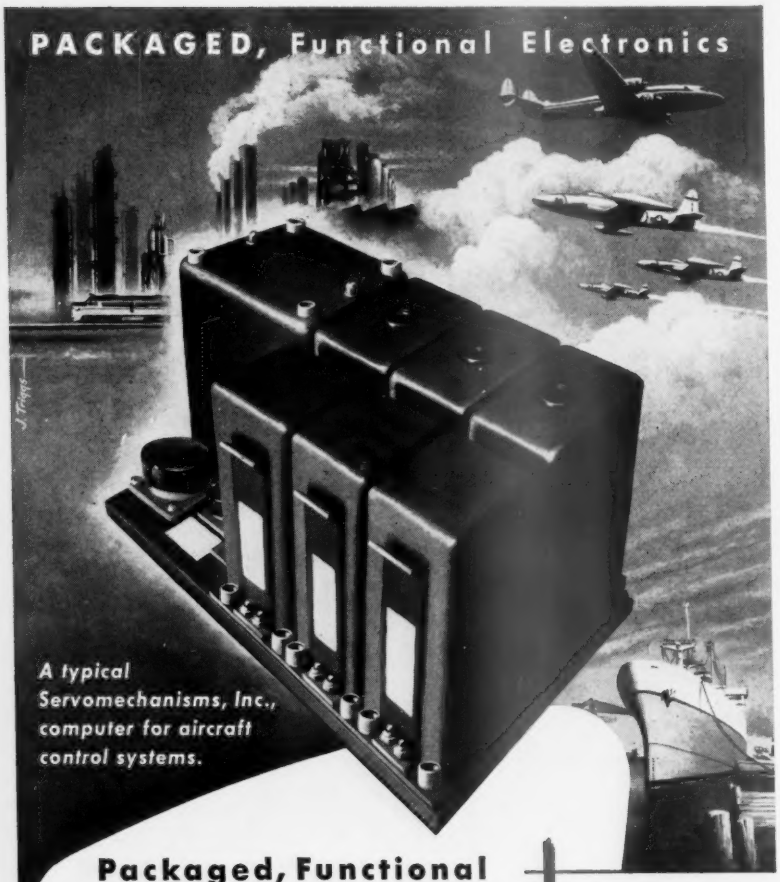

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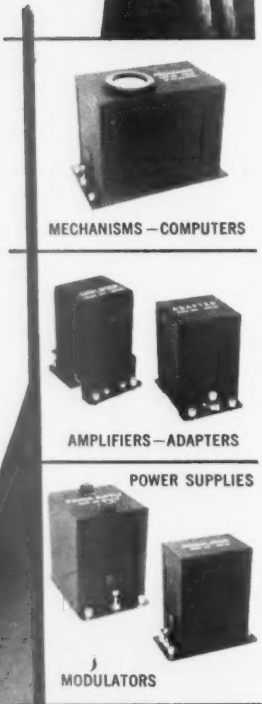

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brushes and slip rings, prolonging brush life. Flow of ambient heat to the alternator, extremely high at missile and jet-aircraft speeds, is minimized by insulation placed between the stator and outside shell of the alternator. The G75 Alternator has a power factor of 80 per cent, weighs 39 lbs., is $12^{5}/_{8}$ in. long and 9 in. in diameter. It is an engine-mounted unit with a 6-in. flange diameter and a 5-in. bolt circle diameter, adaptable to an AND 20002 mounting pad.

• **The M. W. Kellogg Company**. . .Morris W. Kellogg, Founder and Chairman of the Board of M. W. Kellogg, died at the age of 79 at his home on February 22. The M. W. Kellogg Company, today one of the leading organizations in the petroleum field, was begun by Mr. Kellogg in 1901 as a small pipe fabricating shop in Jersey City, N.J.

• **Lockheed Aircraft Corporation**. . .To avoid confusion between the numeral "0" and the letter "O," the U.S. Navy has assigned the letter "V" to Lockheed as the manufacturers designation in the letter and numeral system for the designation of Navy aircraft types and models. Accordingly, the R6O-1 will now be known as the R6V-1; the R7O, as the R7V; the TO-1, as the TV-1; and so on. . .A new fatigue tester with a 500,000-lb. squeeze has been developed and built by Lockheed personnel. This new unit, which can handle parts up to 12 ft. long and 5 ft. wide, measures 20 ft. long by 7 ft. high by 6 ft. wide. The tester can pound its pressures as fast as 2,000 times a minute or as slow as 5 times a minute. It has been described as the most powerful aircraft tester of its type. . .A group of 600 qualified electronics technicians is scheduled to be turned out during 1952 in a new training program. A 12-week familiarization course has been provided for technicians with 5 or 6 years' experience in electronics. For inexperienced trainees, the course is comprised of 27 weeks of fundamentals and up to 14 additional weeks of specialization for men assigned to one aircraft type. An initial 50 electronics technicians are also being trained for Lockheed Aircraft Service, Inc. Minimum background is 1 year of technical training plus 1 year of experience.

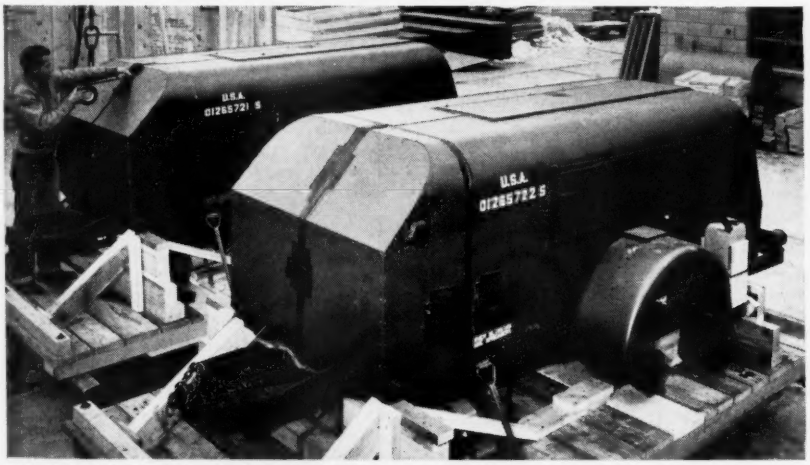
• **Marman Products Company, Inc.**. . .A catalog entitled *Marman V-Band Couplings*, is now available. This booklet lists the functions, selections, specifications, and designs of V-band Couplings.

• **The Glenn L. Martin Company**. . .At the February 21 meeting of the Board of Directors, George M. Bunker was elected to succeed C. C. Pearson, M.I.A.S., as President and General Manager and a Director of the company. At the same time, J. B. Wharton, Jr., was elected Vice-President—Finance, succeeding Richard L. Johnson. Messrs. Pearson and Johnson, whose resignations were accepted at this meeting, are remaining with the company for the nonce to provide assistance and continuity.

• **North American Aviation, Inc.**. . .A prototype of the North American FJ-2 Fury began its first test flight in February. This swept-wing Navy fighter is powered by a General Electric J-47 turbojet engine

GOV'T SPEC specialist relies on Polyken

TAPING SHUT the ignition key slot on the Army's mobile shower unit. Worker uses Polyken Tape No. 214. You can see where he's already sealed a packaged fire extinguisher (upper left), a valve outlet (upper right), as well as the instrument panel which he is just completing.



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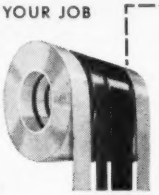

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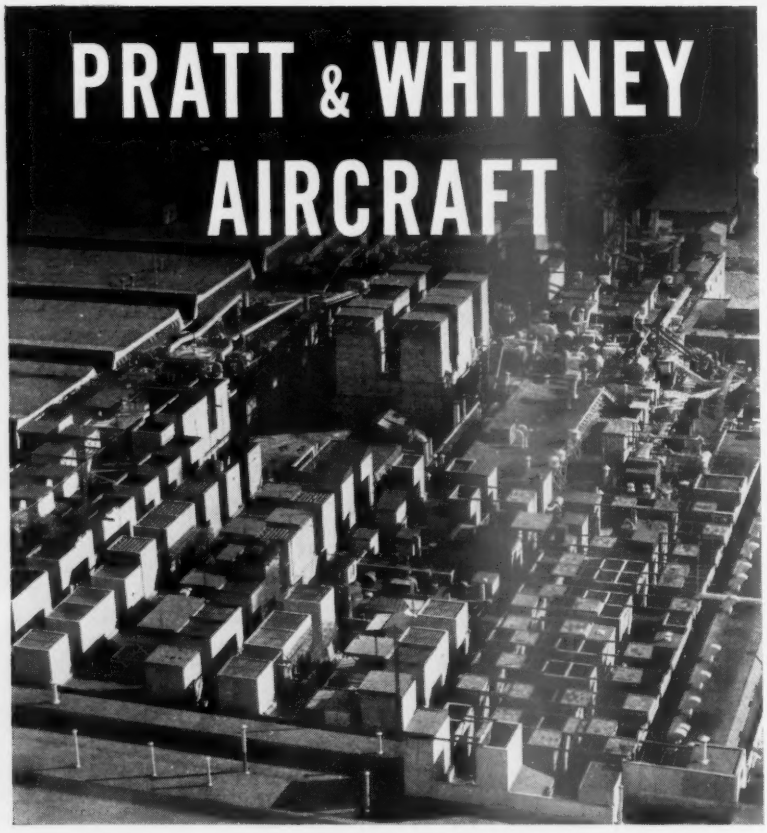

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and is said to be considerably faster than its predecessor, the FJ-1 Fury. The FJ-2 has four 20-mm. cannons and has a 1,000-mile range and a 45,000-ft. service ceiling. The prototype was produced at the Los Angeles plant; production of the FJ-2, however, will take place at the Navy-owned plant operated by North American at Columbus, Ohio. . .Engineers of the Electro-Mechanical Department have been installed in a recently leased 10,000-sq.ft. facility at 8426 Firestone Blvd., Downey, Calif.

• **Northrop Aircraft, Inc.**. . .Students at the Northrop Aeronautical Institute have put the finishing touches on a new miniature jet engine adaptable for small private planes. This engine, known as the Centriflow, has a calculated thrust of 340 lbs. Plans are now under way to install the Centriflow in a Ryan Navion upon the satisfactory completion of extensive ground testing.

• **Phillips Petroleum Company**. . .Harold M. Trimble, Associate Director of Research, Research and Development Department, has been reappointed to the N.A.C.A. Subcommittee on Aircraft Fuels.

• **Piasecki Helicopter Corporation**. . .Deliveries of the HUP-2, which eliminates the tail of the HUP-1, were begun last February. Stability of the HUP-2 is achieved through the use of an autopilot installation adapted by engineers from Piasecki and Sperry Gyroscope Company.

• **Republic Aviation Corporation**. . .A giant $12^1/_2$-ton mobile rocket-engine servicing truck has been designed and constructed by Republic engineers. According to company claims, the truck is the only unit of its kind capable of servicing rocket-propelled aircraft with a bipropellant (i.e.—liquid O_2 and water alcohol) and the pressurizing gas simultaneously from a single source. The truck has a large tank in the rear designed to hold 900 gals. of liquid oxygen. The insulated double walls of the tank are designed to keep oxygen in its liquid state at −300°F. for many hours. At the forward end of the truck is a 700-gal. tank that holds the water-alcohol mixture. This, in combination with eight nitrogen bottles, completes the truck's storage facilities. Additional equipment on the truck includes an Air Force-type B-8 engine-generator, a fire extinguishing system, a compressor, and an electric pump. The entire unit can be operated by as few as two men.

• **A. V. Roe Canada Limited**. . .A production model of the Orenda jet engine has successfully completed the running of the official 150-hour type test, as required by the R.C.A.F. . . .Activities at Avro Canada have been divided into two main operating units, the Aircraft Division and the Gas Turbine Division.

• **Shell Oil Company, Inc.** . . .The addition of small quantities of a chemical known as tricresyl phosphate to aviation gasoline is believed capable of increasing the serviceability of piston engines. By virtue of the counter effect that this chemical appears to have on lead deposits, particularly on the valves and spark plugs, the life span of engine parts may be increased many times. The possibilities of this chemical were discovered by two

New, More Powerful Allison Jet Engines Put Added Sting in the Scorpions

THE NORTHROP SCORPION F-89C—newest all-weather jet interceptor for the Air Force—gets a big power boost from two new Allison J35 engines.

With take-off thrust in the new J35-A-33 engines greatly increased over previous models in the F-89 series, the Scorpion remains the highest-powered interceptor in production in the world today.

This increased power from the improved Allison engines gives the aircraft faster take-off—higher rate of climb—even with heavier fire power and radar equipment.

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Today, Allison engines are depended upon *exclusively* to power the interceptors which guard our shores—a demonstration of confidence based on the unequalled experience of more than 1,300,000 hours in the air—*more time, under all conditions, than all other jet engines combined.*

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teams of Shell scientists working independently in Great Britain and the United States. Three air lines, American Airlines System, KLM, and British Overseas Airways Corporation, are currently carrying out tests.

• **Sikorsky Aircraft Division, United Aircraft Corporation**. . .A Hufford Stretch-Wrap Forming Machine, Model 92, was recently delivered to Sikorsky. This machine forms a sheet measuring 48 in. by 144 in. and is being used in making nose parts, clamshell doors, and body coverings for the Sikorsky Model S-55 helicopter.

• **Solar Aircraft Company**. . .Nacelles made entirely of stainless steel are being produced here for the Navy Lockheed P2V-5 patrol plane.

• **Tinnerman Products, Inc.**. . .A new self-locking nut plate that is made entirely from strip stock and conforms to military aircraft specifications, features a stamped square nut and a fibre washer housed in a sheet-metal retainer. The fiber washer provides the self-locking feature. They are now available in 8-32 and 10-32 sizes.

• **Vickers, Inc.**. . .Edward Doucet, Jr., was appointed Advertising Manager of Vickers. Mr. Doucet has been with the company for the past 8 years, the last 5 years being in the Sales Department.

• **Westinghouse Electric Corporation**. . .At a recent stockholder's meeting, it was disclosed that Westinghouse will build the complete power plant, including the nuclear reactor and the associated propulsion equipment, for the atomic-powered submarine, U.S.S. "Nautilus." At the same time, it was reported that the corporation will also build what is said to be the most powerful machinery ever designed for ship propulsion: the turbine and gear assembly for the aircraft carrier, U.S.S. "Forrestal.". . .A panel mounting rack, incorporating a mechanism for rapid installation or ejection of control or amplifier panels, has been developed by the Aircraft Department. . .An 18-page booklet (B-5428) on airport lighting equipment selection and electrical requirements is now available by writing to Westinghouse, Box 2099, Pittsburgh 30. . . J. R. Weaver, who was a Vice-President of Baldwin-Lima-Hamilton Corporation, has been named Vice-President in charge of Manufacturing at Westinghouse.

Meet Your Section Chairman

Harold D. Hoekstra

Washington Section

Harold Hoekstra first became seriously interested in aviation on July 4, 1911, when, at the age of 8, he saw Leonard Bonney fly a Wright biplane from a ball park in his home town of Battle Creek, Mich. It became more serious when, after work on the repair of Canuck and Jenny trainers, he built a monoplane powered with an English J.A.P. motorcycle engine in 1920 as he finished high school. Fortunately for him, he says now, the power loading prevented doing more than grass-cut like the World War I type of clipped-wing Penguin trainers. He finally soloed in proper style in 1930 in an OX-5 Travel Air biplane at Blue Ash, near Cincinnati, Ohio, and currently holds a commercial pilot's certificate.

Mr. Hoekstra received his B.S. in aeronautical engineering from the University of Michigan in 1929. In working his way through college, he spent several years on drafting and engineering work on newspaper printing presses and farm machinery and also worked for a time on aircraft and engine designs for consultants. He took his first two years of college at Michigan State before transferring to Ann Arbor.

After graduation from Michigan, Mr. Hoekstra became chief engineer of Crosley Aircraft Company, Cincinnati. Within two years, a high-wing four-place cabin monoplane, a two-place training biplane with an inverted air-cooled engine, and a small high-wing monoplane with folding wings had been constructed and flight tested. He reports that probably the first actual flight tests of spoilers as a lateral control device were made here early in 1930. An installation of spoilers was made on a Crosley biplane, and the lag characteristic was then noted, as well as the excellence of spoilers as a spin recovery device. Recovery from six-turn spins was cut from $1^1/_2$ turns down to $^1/_2$ turn.

What Mr. Hoekstra terms the "economic softness" of the early 1930's was the cause of several moves—to Ford at Dearborn, where he did engineering on the trimotors and to Curtiss at Buffalo where he worked on military aircraft. In July, 1933, he moved to Wayne, Mich., joining the Stinson Aircraft Corporation. Here he did design work and was flight test engineer and project engineer on single-engined and trimotor aircraft. These aircraft ranged from the straight and gull-wing Reliants on wheels, floats, and skis, to the trimotor transports built for different air lines.

In October, 1937, Mr. Hoekstra joined the C.A.A. as an aeronautical engineer in airworthiness work and advanced to the position of Chief Engineer, Aircraft Division. During the past year, he has acted as Assistant Director for Prototype Aircraft Development, Office of Aviation Safety. Activities in the C.A.A. have included C.A.A. liaison with Wright Field in World War II, the supervision of work on light-plane conversions to military training gliders, engineering work with Fred Weick on the C.A.A.-Texas A&M agricultural airplane, and membership on A.C.C., A.N.C., and N.A.C.A. committees and on the first U.S. delegation to I.C.A.O. at Montreal in 1946. Last June, he headed the C.A.A. Foreign Survey Group, a Government-industry team that studied foreign transport aircraft progress in Europe. He has been a member of the N.A.C.A. Aerodynamics Committee since 1944.

He has presented papers on structures, flutter, design, airworthiness requirements, and other subjects before the I.A.S., S.A.E., and other groups and has been granted a number of patents.

Mr. Hoekstra is a Fellow of the Institute, an Associate Fellow of the Royal Aeronautical Society, and a member of the Society of Automotive Engineers.

In November, 1931, Mr. Hoekstra married Laura Barker of Glendale, Ohio, a graduate pharmacist (Cincinnati College of Pharmacy and Ohio State Board), and now two girls, Betsy, 15, and Ann, 9, and two boys, Tommy, 12, and Dirk, 7, help keep things lively around their home in Arlington, Va. His hobbies include history, a home workshop, and taking the children for hops in his partly owned Piper Pacer.

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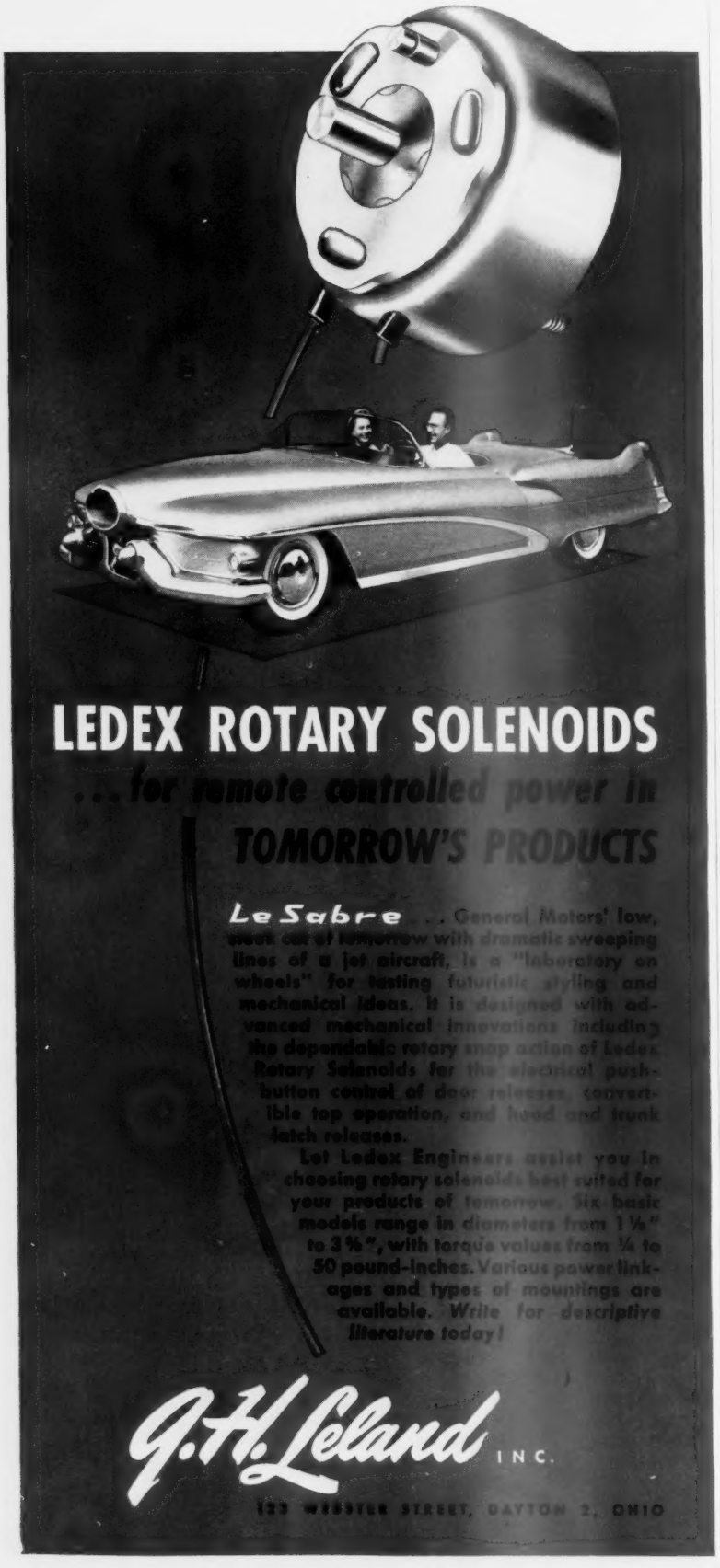
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I.A.S. Sections

Boston Section

E. E. Larrabee, *Secretary*

The December 12 meeting was devoted to a discussion of the problems of helicopter instrumentation. R. G. Ballard of General Electric Company's Instrument Development Group was the speaker of the evening. He compared the problems of instrumenting the helicopter and the airplane. In general similar instrumentation problems prevailed with certain noteworthy exceptions: (1) The presence of a clutch between the engine and the rotor of a helicopter required separate tachometers, usually on a common dial, as compared with the airplane with one tachometer for both engine and propeller; (2) the ability of the helicopter to hover and to move sideways or backwards required an anemometer in conjunction with a yaw vane to indicate air speed; and (3) the large-amplitude low-frequency vibrations experienced in helicopters forced unusual instrument maintenance problems on the operator. British experience, for example, showed that gyro horizons had to be overhauled every 200 hours.

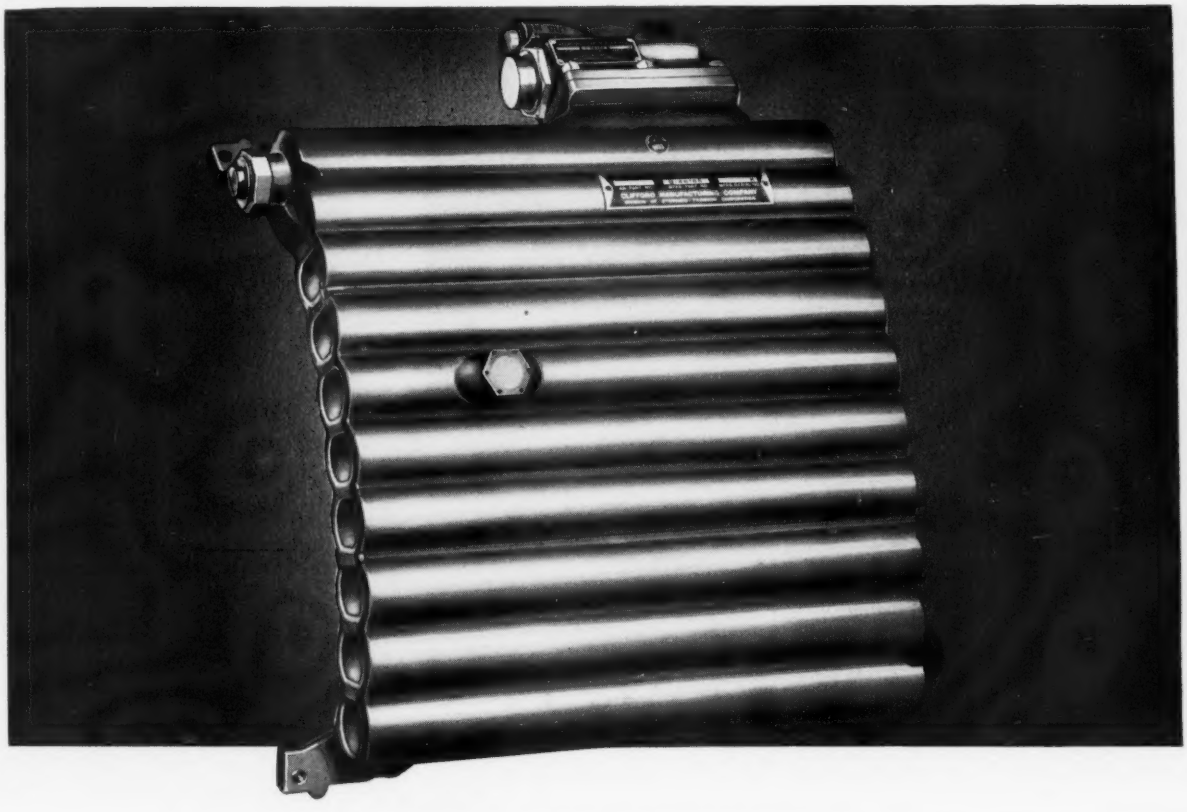
It was also pointed out that the poor dynamic stability of current helicopters—particularly in the rapid divergence in roll—made blind flying difficult, if not impossible, when a human pilot attempted to stabilize the machine by reference to a gyro horizon. In fact, the C.A.A. prohibits blind flying of helicopters not stabilized by automatic pilots.

Chicago Section

Alfred F. Stott, *Secretary*

On February 14, members and guests of the Chicago Section met at the Museum of Science and Industry in Chicago. Forty-seven attended a 6:30 dinner in the Museum Dining Room and then viewed several electronic and radio exhibits that were open that evening. At 8:00 p.m., Chairman Robert H. Wendt called the group of 85 to order in the auditorium. Lee W. Sims, Chairman of Student Activities Committee, outlined the Student Paper Contest to be held March 13 at Illinois Tech. Mr. Wendt introduced Dr. H. L. Hull, Program Chairman, who in turn introduced the speaker, Dr. Albert C. Hall, Associate Director, Research Laboratory, Bendix Aviation Corporation, who spoke on the "Trends in the Development of Control Systems for Aircraft."

Dr. Hall mentioned that the accessory business accounted for about 50 per cent of the military aircraft contracts and, by this fact, much stress



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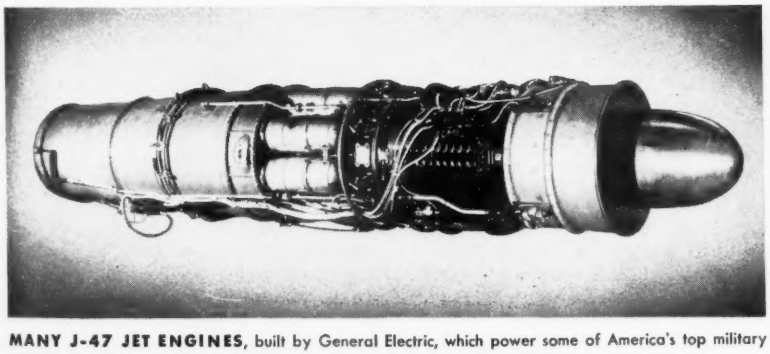

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At a Cleveland-Akron Meeting: *An informal shot snapped at the January 22 meeting of the Cleveland-Akron Section shows (from left to right): Thomas J. Herbert, formerly Governor of Ohio; Dr. E. R. Sharp, Director, Lewis Flight Propulsion Laboratory, N.A.C.A.; and E. W. (Pop) Cleveland, Section Chairman and Vice-President and Director of The Cleveland Pneumatic Tool Company.*

will have to be placed on reliability. Automatic controls are intended to give pilot relief, safety, and better performance. Engine controls, particularly those associated with jet engines, have been perfected to the point where they are ahead of aircraft controls. The Bendix PB-10 Automatic Pilot was explained in detail. Schematic control-system diagrams were shown with slides. He expressed the need for a good reliable low-priced gyro and the desirability of smaller size and lighter weight units. He felt that automatic controls in general had accomplished about 90 per cent of the job in pilot relief, but that they were not up to that value in reliability.

An interesting question and answer session followed. Chairman Wendt closed the meeting at 9:30 p.m.

Cleveland-Akron Section

Harrison C. Chandler, Jr., *Secretary*

"Some Factors Influencing the Airfreight Carriers' Selection of Flight Equipment" was the title of the paper read by Henry P. Huff, Vice-President for Operations, Slick Airways, Inc., at the January 22 meeting of the Cleveland-Akron Section. About 200 members and guests attended this meeting which was held at the Cleveland plant of Jack & Heintz, Inc.

The program of activities for the evening included conducted tours of the Jack & Heintz plant, a social hour, and a buffet dinner. Chairman E. W. (Pop) Cleveland presided.

Mr. Huff discussed in his paper the important factors that maximize profits per dollar of invested capital in the operation of an airfreight carrier. By way of indicating the rapid growth within the airfreight business, he pointed out that the total volume of airfreight carried by the U.S. domestic air lines during the last six months of 1945 was 1,350,000 ton-miles, while the total for the corresponding period in 1951 is estimated at about 235,000,000 ton-miles.

The successful operation of an airfreight carrier, Mr. Huff explained, requires that the optimum compromise be made among the cost per ton-mile of service, the average scheduled speed of delivery, and quality. Quality, as used here, includes schedule reliability as well as the delivery of freight in the same condition as it was received at the point of origin.

Mr Huff was of the opinion that, of all the factors influencing the profitability of the airfreight carrier, the type of flight equipment used was the most important. This situation exists because 65 per cent of the total expenses are actual aircraft operating costs, because the schedules are dependent upon the airplane's performance, and because 50 per cent of the controllable delays and 20 per cent of the damage claims are attributable to the aircraft used.

In considering the various types of available aircraft, Mr. Huff felt that the profit-earning capacity per dollar of initial cost was the one of prime importance. Aircraft operating costs are far greater than loading costs, and hence emphasis must be given to performance of the aircraft rather than to the ease with which it can be loaded and unloaded. This situation holds true today because utilization is limited to overnight operations. It follows that the loadability of the airplane may assume greater importance in years to come.

Hagerstown Section

Robert E. Braus, *Secretary*

The January 29 meeting was held in the Antrim Room of the Hotel McLaughlin at Greencastle, Pa. Approximately 50 members and guests were present.

After a short business meeting, the speaker of the evening, Arthur Matzke, Systems Design Engineer, Bureau of Aeronautics, Washington, D.C., was introduced by Henry Weisenburger of the Program Committee.

Mr. Matzke's subject, "Hydraulic Systems, Design, and Development," was particularly timely inasmuch as the Fairchild C-119 airplane is now being newly equipped with hydraulic landing gear and flap actuation, replacing formerly used electric actuation.

Mr. Matzke reviewed the history of hydraulic system development from the first systems that consisted solely of hydraulic brakes through the current complex 3,000 lbs. per sq.in. systems to the projected 5,000 lbs. per sq.in. systems for the near future. His interesting and informative talk was followed by a lively discussion and question and answer session.

San Diego Section

H. L. Braasch, *Secretary*

The February dinner meeting was held at 7 p.m. on February 14 at the Henry Langhorst Cafe in San Diego. Chairman W. C. Heath read a letter that had been received from Vice-Admiral Sprague inviting members of the San Diego Section to attend a Carrier Field Trip on April 14.

Vice-Chairman R. P. White introduced the speaker of the evening, William F. Carr, Chief Applications Engineer, Lear, Inc. Mr. Carr's subject was "Autopilots and Guided Missiles." Mr. Carr has had a wide range of experience in the design of autopilots and missile guidance control systems. He played a prominent role in the development of the Lear F-5 autopilot and has contributed to the design of aircraft control and indicating systems such as the I.L.S. approach couplers and vertical descent indicators.

Mr. Carr briefly discussed the use of the Approach Coupler that permits an entirely automatic blind landing to be made through the combined aid of the I.L.S. system and the autopilot. It is only necessary for the pilot to turn a switch to actuate the Approach Coupler. It was pointed out in connection with the development of autopilots that two of the major problems confronting the autopilot designer were the design of an erection switch and the design of a serviceable servo clutch. The "powdered iron clutch" was discussed briefly

and was cited as the most promising clutch to date. Mr. Carr's talk was supplemented with several models that included a model of a V-2 missile capable of tracking a "light" source used as a moving target.

Following the talk, the meeting was adjourned by Chairman Heath.

San Francisco Section

Don O. Horning, *Chairman*

The new officers for the San Francisco Section are: Chairman, Don O. Horning; Vice-Chairman, H. Julian Allen; Secretary, James W. Craft; and Treasurer, Steven E. Belsley.

Seattle Section

Dick FitzSimmons, *Secretary*

Dr. C. Stark Draper, Head of the Department of Aeronautical Engineering of Massachusetts Institute of Technology and Director of its Instrumentation Laboratory, addressed a joint meeting of the M.I.T. Club and the local I.A.S. Section on February 5 on the subject, "Brains for Metal Birds." In a most interesting and highly enlightening lecture, Dr. Draper outlined the processes involved in actuating parts of the human body. He then showed their correlation with the receiving elements, signal transmitting systems, regulators, and decision generating systems that we are presently building into our flying vehicles. He showed the vast stores of knowledge on controls which nature has assembled through countless centuries of trial and error in her constant search for perfection. By comparing this vast store of knowledge with its meager bits of information we have mastered as designers, he was able to do some crystal-ball gazing and make some predictions as to what could be expected of the next generation of flying vehicles and how closely they might approach the completeness of self-contained entities.

An analysis of the parallel-system or single-system reliability as compared with the multisystem reliability found in nature gave rise to a number of conflicting opinions as to which direction our major effort should be directed. These opinions were expressed in the general discussion period following Dr. Draper's presentation.

Texas Section

C. L. Seacord, Jr., *Secretary*

The most successful meeting of recent years was enjoyed by the Texas Section on January 24 at Midway Inn, Arlington, Tex. It was in the form of an open dinner meeting, and the program, which featured a panel of test pilots,

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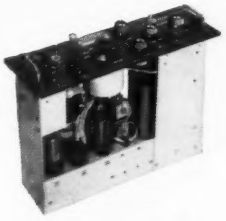

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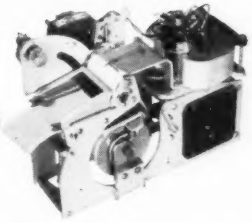

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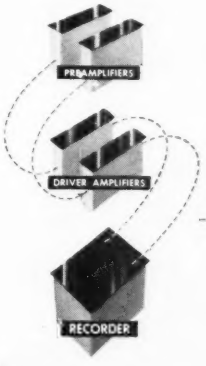

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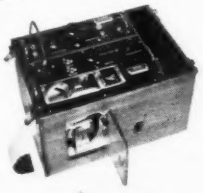

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attracted 180 dinner guests and about 300 people total. The panel of pilots consisted of: B. A. Erickson, Manager of Flight, Convair, Fort Worth; A. S. Witchell, Supervisor of Flight Operations, Convair, Fort Worth; Paul Thayer, Chief of Sales, Chance Vought Aircraft Division, United Aircraft Corporation; John McGuyrt, Chief Test Pilot, Chance Vought; Joseph Dunne, Chief of Experimental Flight, Bell Aircraft Corporation, Fort Worth; and Elson Smith, Experimental Test Pilot, Bell Aircraft, Fort Worth.

The program was entitled "The Pilot Speaks" and consisted of answers to and discussions of questions submitted by the members. W. A. Clegern, Chief of Engineering Flight Test, Convair, introduced each of the pilots and acted as moderator during the question and answer session. The questions had been preselected in order to ensure that a majority was of general interest; this, coupled with the professional qualifications and excellent showmanship of the speakers, provided a series of discussions that, from beginning to end, held the interest of the rather mixed audience.

The questions varied from the routine "What was your most exciting moment?" to queries concerning the finer points of the handling qualities of fighters, bombers, and helicopters.

One opinion upon which all the pilots were unanimous was that properly planned and conducted test flying, whether experimental or production, is not unduly dangerous and is the most desirable form of professional flying.

Washington Section

J. H. Sidebottom, *Secretary*

The Naval Ordnance Laboratory, White Oak, Silver Spring, Md., was host to the Washington Section on January 8. Dinner was served in the N.O.L. cafeteria to more than 200 members and guests of the I.A.S.

After dinner, Chairman H. D. Hoekstra turned the meeting over to Dr. R. J. Seeger, who is Head of the Aeroballistic Research Department, N.O.L. After calling on Rear Adm. W. G. Schindler, N.O.L. Commander, for a few notes of welcome, Dr. Seeger discussed the various phases of the aeroballistic program at N.O.L. and introduced the persons directly in charge. He emphasized the importance of the fact that the people and not the facility itself establishes the quality of the research produced.

The meeting was then adjourned to the auditorium where Mr. Hoekstra called on Rear Adm. M. F. Schoeffel, Chief, Bureau of Ordnance, to conduct the meeting. Dr. H. H. Kurzweg, Deputy Chief, Aeroballistic Research De-

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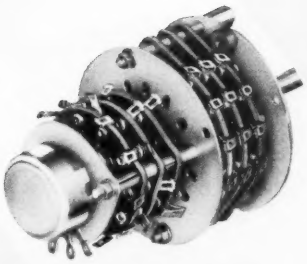

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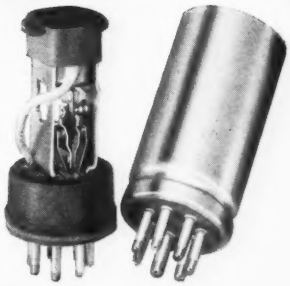

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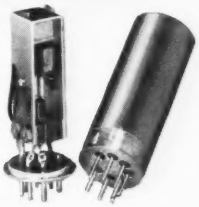

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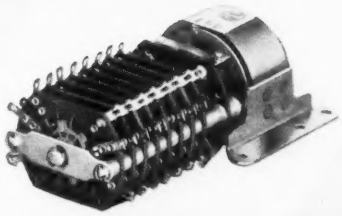

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partment, N.O.L., presented a discussion on "Aeroballistics." He pointed out how in former years the aerodynamicist has been concerned with the subsonic flow problems as related to aircraft, while the ordnance people have been firing supersonic projectiles with no special regard to the flow phenomena. In recent years, aircraft with higher speeds have been invading the realm of ordnance. These two fields of endeavor have made substantial contributions to each other, and the result is missiles and aircraft that are similar in appearance—i.e., slender body and swept wing and tail surfaces.

Both ordnance and aircraft people are now interested in increasing the speed of their respective craft. This introduces serious problems in heat transfer and boundary layer which in turn is interrelated to the surface friction and base pressure, each representing about one-third the total drag for a slender body at Mach 5.0. The determination of the above interrelations is one of the immediate objectives of the N.O.L. research program.

Dr. P. Wegener, who is in charge of the hypersonic wind-tunnel research at N.O.L., pointed out in his talk the need of utilization of the wind-tunnel and free-flight ranges for simulating conditions of free flight of the full-scale missile or airplane. Simulating very high speeds (hypersonic $M > 5$) in the wind tunnel requires a high supply pressure. Expansions to high Mach Numbers result in low temperatures and condensation of the air itself. To eliminate this air condensation, the supply air must also be preheated. In the N.O.L. wind tunnel, Mach Numbers up to the order of 10 have been reached without condensation. In the test sections, the temperatures of the air surrounding the model are extremely low and the stagnation temperatures are in order of magnitude of the supply temperature (about 1,000°F. at Mach 10). In free flight, however, stagnation temperatures reach thousands of degrees. These special effects of high temperatures at high Mach Numbers cannot therefore be simulated in the tunnel and are being studied at N.O.L. by firing models in the firing range. At N.O.L. so far, small missiles have been propelled in air by P. Thurston up to Mach 10. Mach Numbers of 13 have been reached by Slawsky, Schwartz, and Eckerman in bromine.

After the meeting, transportation was provided to the wind-tunnel building. Here, Dr. G. L. Shue, Assistant Chief for Aeronautical Engineering, gave a demonstration of the 40- by 40-cm. wind tunnel blowing at Mach 2.48 and discussed various aspects of research work in the wind tunnels related primarily to missile design. Dr. Shue discussed the principle of a simple internal balance and the method of reducing the "Helipot" readings to nondimensional aerodynamic coefficients. He also showed an interesting film on the airflow characteristics for starting and stopping conditions in the 40- by 40-cm. tunnels.

Following this demonstration, conducted tours were made to other displays in the wind-tunnel building, which included the following: (a) Aerothermodynamics—a display of 40- by 40-cm. wind tunnel No. 2 and associated instrumentation; (b) Aeroballistics—a display of wind-tunnel models, internal strain-gage balances, free-flight display from the Pressurized Ballistics Range, and a spinning model that simulates a spinning projectile in free flight; (c) Operations—display of a steel and a plaster nozzle and the main control board; (d) Applied Mathematics—display on the use of the I.B.M. machines for wind-tunnel data reduction; (e) Aerophysics—a demonstration of the use of the interferometer for the 18- by 18-cm. wind tunnel and other associated instrumentation; and (f) Hyperballistics—an impressive display of the hypersonic wind tunnel (12- by 12-cm.) in operation at Mach 7.3.

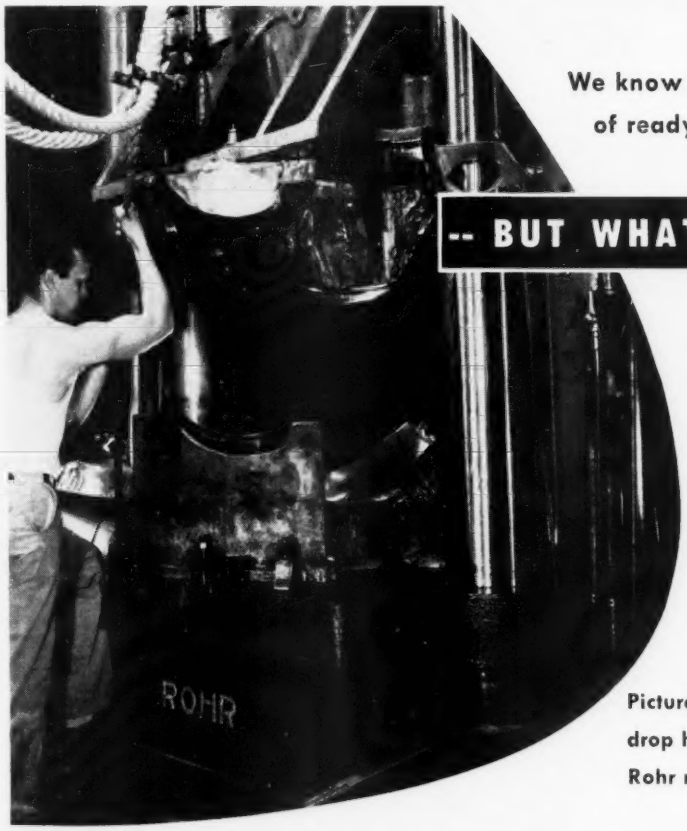
Dr. Seeger, I. M. Nestingen, L. Potter, J. Crown, H. Staab, all of N.O.L., made the necessary arrangements for this meeting. Members and guests wish to express their gratitude to N.O.L. and the committee and staff who were responsible for the arranging of one of the most interesting section meetings in the history of the Washington Section.

▶ The February 5 meeting of the Washington Section, which was devoted to helicopters, was the largest combined dinner and section meeting that we have had for several years. Over 150 people attended the dinner and approximately 350 persons attended the section meeting. The great interest and attendance at this meeting was due in no small measure to the cooperation of the American Helicopter Society, which acted as joint sponsor of the meeting and provided the speakers.

Lt. Colonel R. R. Williams, U.S.A., presented an interesting paper on the use of helicopters by the Army as well as many of his personal experiences in the Korean operations. Colonel Williams outlined the growth of Army aviation and the efforts that are being made to integrate helicopters and other aircraft types into the various arms and services of the Army as organic vehicles. The use of the helicopter for transportation, communication, and evacuation by the Army was graphically portrayed by the speaker and was later emphasized in a film, *The Guardian Angel*, presented by Sikorsky Aircraft Division of United Aircraft Corporation.

Experiences of flying helicopters in combat operations of the U.S. Marine Corps in Korea were vividly described by Major D. W. McFarland, U.S.M.C., in his presentation of the Marine uses of helicopters. Major McFarland gave credit to many of the models now being used in Korea for saving more than 6,000 lives in evacuation operations. Of particular importance to Marine operations were the resupply missions in which helicopters delivered in 1 hour the equivalent of supplies requiring 500 native bearers over a 16-hour period in country through which trucks could not be used at all. Of especial interest was the speaker's description of the methods of control of helicopters as

Washington Section Meeting: *The I.A.S. Washington Section held its January 8 meeting at the Naval Ordnance Laboratory, White Oak, Md. In the above photograph, the camera caught the members of the head table just prior to their repairing to the N.O.L. auditorium for the technical session. From left to right are: J. E. Dougherty, Jr., Aeronautical Engineer, C.A.A.; Dr. R. D. Bennett, N.O.L. Technical Director; Dr. Hugh Dryden, N.A.C.A. Director; Rear Adm. M. F. Schoeffel, Chief, Bureau of Ordnance; Rear Adm. W. G. Schindler, Commander, N.O.L.; Harold Hoekstra, Chief Engineer, Aircraft Division, C.A.A.; Rear Adm. T. C. Lonnquest, Assistant and Deputy Chief, Bureau of Aeronautics; Commander Pooler, N.O.L. Technical Liaison Officer; Dr. R. J. Seeger, Chief, Aeroballistics Research Department, N.O.L.*



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practiced by the Marine Corps on a central rather than a decentralized basis.

The fact that a continually expanding military acceptance of the helicopter will serve to bring about rotary-wing aircraft of transport proportions for civilian use in the near future was underlined by Stanley Hiller, Jr., President of Hiller Helicopters and Vice-Chairman of the Helicopter Council, in his presentation as the industry's spokesman in the February 5 program. Mr. Hiller reviewed the technical progress made possible since the military needs built up a backlog of approximately $400,000,000 in orders for helicopters of various types and designs. Mr. Hiller pointed out that the present state of development of the art could not have been achieved in perhaps a decade without the impetus of the utilitarian value demonstrated so thoroughly in Korea.

Major Samuel B. Brown, U.S.A.F., told of the operational suitability tests of the Sikorsky H-19 in Korea which were an extended series of tests following the work done at the Air Proving Ground at Eglin Air Force Base, Fla. For these tests, an H-19 was transported in a C-124 to Japan and thence to Korea, complete with pilots, mechanics, and field engineers. During the 40 days of this test operation in Korea, 93 patients were evacuated from front-line positions to mobile hospitals, six pilots were rescued from behind enemy lines from points up to 150 miles, and miscellaneous supply missions were carried out for the medics and operational units. Major Brown highlighted his presentation with a number of recommendations on the necessity for maintaining historical records on major components of helicopters, the need for simplified fastening devices for cowling, inspection plates, fuel and oil lines, etc., and a plea for reduction in weight wherever possible in all parts of the helicopter. Of particular importance is the need for light helicopter-transportable maintenance and servicing equipment, especially in operations such as those being conducted in Korea.

The meeting was concluded with the presentation of the aforementioned film, *The Guardian Angel*, by Jack Beigle. The meeting was led by Col. Bruce Holloway, Deputy Director of Research and Development, U.S.A.F. Headquarters, who conducted the questioning at the conclusion of the meeting.

The Washington Section was distinctly honored at this meeting to have the pioneer helicopter designer, Igor Sikorsky, and the first helicopter pilot, Col. Frank Gregory, in attendance at this session.

Student Branches

Academy of Aeronautics

The February 13 meeting was presided over by the outgoing Chairman, Calvin D. Holbert. An election of officers which was held at this time gave the following results: Chairman, Nicholas G. Kruger; Vice-Chairman, Roger Bush; Corresponding Secretary, Vasant D. Wagle; and Treasurer, Bruno Germano. The post of Recording Secretary is to be filled later. Twenty-six students were present.

The Catholic University of America

Forty persons attended the January 11 meeting to hear Edwyn Eddy, XF-91 Project Engineer for Republic Aviation Corporation, speak on "The Evolution of the XF-91." A film provided by Mr. Eddy entitled *Higher and Faster* was shown after his talk. Chairman Earl W. Erickson presided.

University of Colorado

Thirty persons attended the February 12 meeting at which a film, *Behind the Scenes at Convair*, was shown. This was followed by a talk by Alex C. Burr, a campus representative for Religion in Life Week, who spoke on religion in relation to the engineer. Chairman Burt R. Benson presided.

University of Detroit

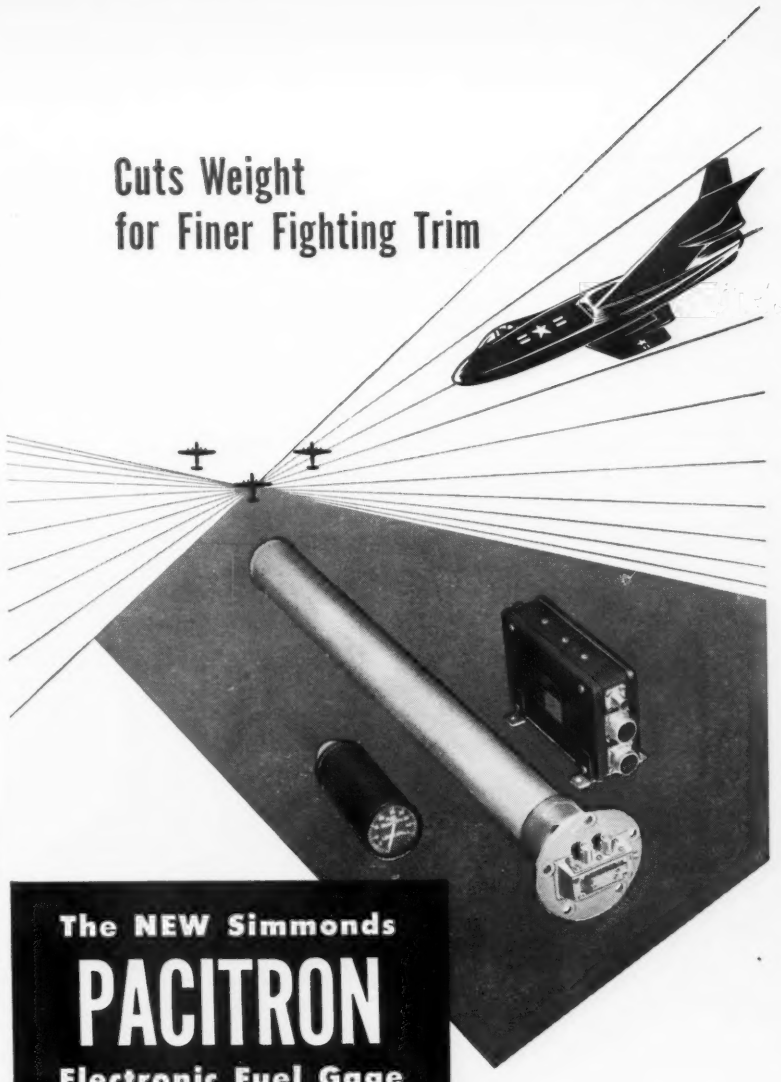
On February 12, Dr. Frederich W. Ross, Professor of Aeronautical Engineering at the University of Detroit, gave an illustrated lecture on the "Ross Flight Control System." Members of the University of Detroit's Flying Club and Mechanical Department were guests at the meeting, which was attended by a total of 38 persons. Chairman George Paul Himes presided.

University of Illinois

It was announced by the presiding officer at the February 13 meeting, Vice-Chairman Don Pfueffer, that the newly elected Chairman, Loren Anderson, was unable to serve in that capacity. As a result of a special election held at this meeting, Frank Vileta was elected to the post of Chairman. Sixteen students were present.

Louisiana State University

At the February 14 meeting, Henry Williams was elected Secretary to fill the unexpired term of Jerry Carpenter, who resigned from the post. It was also



The new Simmonds Pacitron saves weight in modern jets, where the accuracy of electronic fuel gaging is vital to tactical effectiveness. With its miniaturized amplifier-bridge, the Pacitron climaxes 10 years of Simmonds leadership in capacitance gaging. It provides an accurate indication regardless of complex tank geometry and can be adapted to a wide variety of fuels.

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voted at the meeting to rent a post office box. Accordingly, all correspondence for the L.S.U. Student Branch will be addressed to Box 8821, University Station, Baton Rouge, La. Chairman Claude J. Cantreel presided; 6 persons were present.

Massachusetts Institute of Technology

On February 26, elections of officers took place with Chairman Alfred Blackburn presiding. The results were as follows: Chairman, James Flanders; Vice-Chairman, John Martucelli; Secretary, Maurice Gionfriddo; and Treasurer, John Stewart. Twenty-one persons were present.

New York University

During the first semester of the 1951–1952 academic year, a total of about twelve films were shown. These have included: *The Flying Wing, Structure of the B-25, The Martin 2-0-2, The Wing Destruction Test of the PBM,* and various films from the N.A.C.A.

A field trip was held jointly with the Heights Rocket Society, and a tour was made of the Grumman Aircraft Engineering Corporation.

All of the meetings were presided over by Chairman Donald Mandell.

University of Notre Dame

The February 21 meeting, attended by 13 persons, was called to order by Chairman Robert Seebold. William Flick, a Junior in the Department of Aeronautical Engineering, spoke on the subject of "Flight Instruments."

The Ohio State University

On February 6, Harold Herring, Supervisor of the Power Plant Components Section, North American Aviation, Inc., spoke on "Power Plant Components." Chairman Richard G. Docken presided; 15 persons were present.

The University of Oklahoma

Chairman Walter I. Myers presided at the January 10 meeting at which 40 persons were present. The speaker was Prof. L. A. Comp, Chairman of the Department of Aeronautical Engineering, who spoke on "Engineering Jobs in an Aircraft Plant." A film entitled *NACA Research* was shown.

▶ On February 11, Jack C. Hanes, Supervisor of the Weight Control Section, Chance Vought Aircraft Division, United Aircraft Corporation, spoke on the subject, "Functions of a Weight Control Section." Eleven students were present.

Parks College of Aeronautical Technology

Chairman Joseph Witko, Jr., opened the February 14 meeting at which an election of officers took place. The following students were elected: Chairman, Eugene J. Swick; Vice-Chairman, Richard L. Morgan; Recording Secretary, Neil J. Pierce; Corresponding Secretary, Jack E. Hanzlik; and Treasurer, Ray J. Tolosko. At the conclusion of the business meeting, a talk was given by James L. Munier, of Parks, on "Analytical Derivations of Beam Deflection Equations." Thirty-five persons were present.

The Pennsylvania State College

The speaker at the March 7 meeting was Mr. Hunter who is with the N.A.C.A. Mr. Hunter's topic was "Research with the N.A.C.A." Chairman George Page presided, and 23 students were present.

Purdue University

A joint meeting was held on February 12 with the Purdue Chapter of the American Rocket Society. The speakers were R. B. Foster, Research Group

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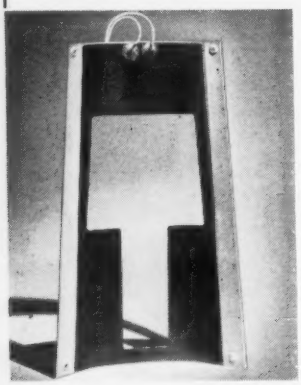

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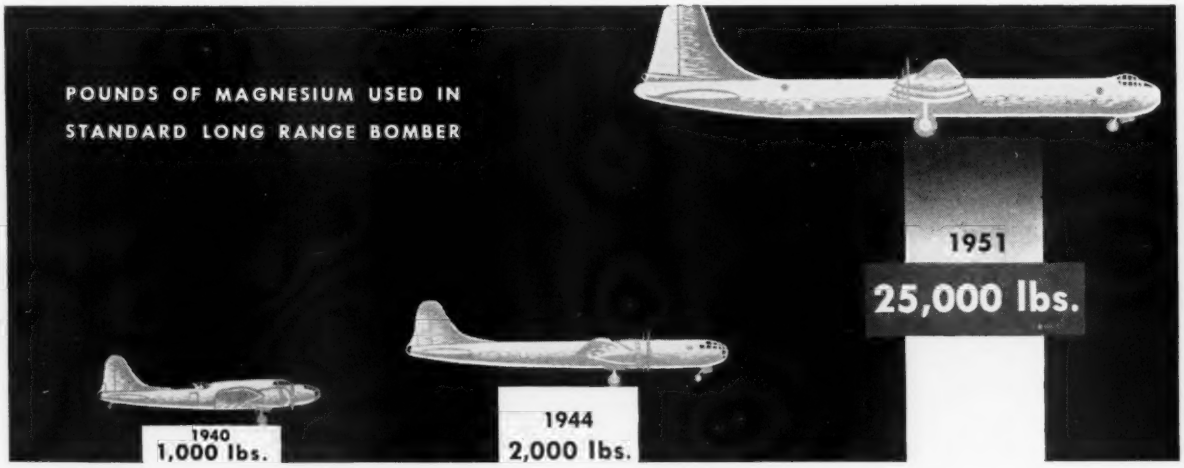

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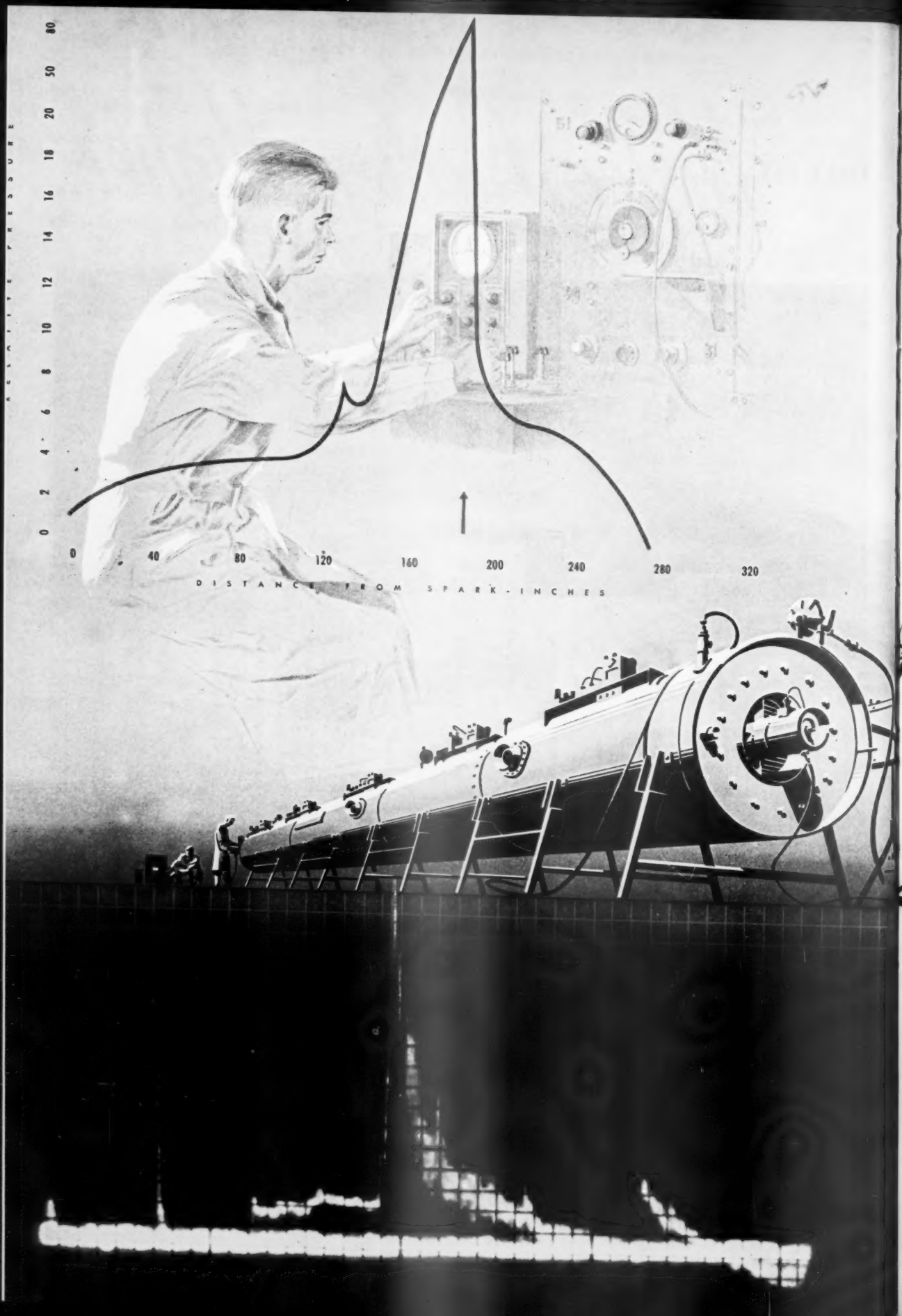
RELATIVE PRESSURE
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DISTANCE FROM SPARK - INCHES

GROWTH OF A FLAME

What really happens when a flame front accelerates to seven times the speed of sound? No one knows the whole story. But the real nature of these combustion phenomena is being unfolded in a fundamental research program sponsored by the American Gas Association, and conducted at the Toledo laboratories of Surface Combustion Corporation. Already this project has provided some fascinating new concepts of flame propagation behavior.

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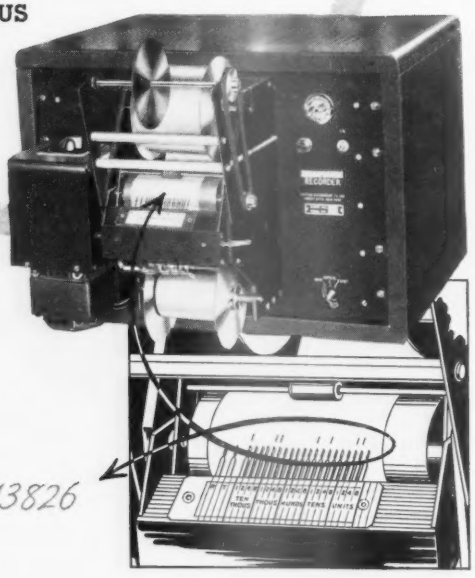

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Leader of Bell Aircraft Corporation's Rocket Department, and Robert Youngquist, Development Staff Engineer, Reaction Motors, Inc. Mr. Foster spoke to an audience, numbering some 250 persons, on the subject, "Development of the XS-1." Mr. Youngquist spoke on "Aircraft Rocket Motors." Three motion pictures that were shown in conjunction with the addresses were: *The Bell XS-1*, *Progress in Rocketry*, and *The Bell XS-1 Transonic Research Plane*. The presiding officer was Chairman Henry E. Covert, Jr.

▶ An election of officers was held recently with the following results: Chairman, Henry Covert; Secretary, Homer Morgan; and Treasurer, Edwin Roof. The office of Vice-Chairman will be filled at a later date.

Rensselaer Polytechnic Institute

On February 20, James A. O'Malley, Aerodynamicist from Bell Aircraft Corporation, gave a lecture on "Flight Research Airplanes, X-5 and X-1." Shown in conjunction with this talk were two films, one a 400-ft. work print film on the X-5 and the other on the *XS-1 Transonic Research Airplane*. Chairman Frank T. Suppies presided; 96 students were present.

The University of Texas

An election of officers was held at the February 19 meeting with the following results: Chairman, Soren Jenson; Vice-Chairman, Harold Arterburn; Secretary, Johnson A. Jenkins; and Treasurer, Norman Cooper. The Faculty Adviser is W. H. Shutts. A film, *Aircraft Maintenance*, concluded the meeting. Chairman Soren Jenson presided; 12 students were present.

Tri-State College

Professor Quintin Hawthorne, Faculty Adviser, gave a report on the I.A.S. Twentieth Annual Meeting. This report was delivered at the February 7 meeting of the branch; Chairman Jack Jewell presided.

▶ Two motion pictures were shown at the February 21 meeting, attended by 40 persons and led by Chairman Jack Jewell. The films were *How Not To Conduct a Meeting* and *The Banshee*.

United States Naval Academy

On January 25, a film from Shell Oil Company, *Aircraft Controls*, was shown to the 39 attending students. Midshipman Charles H. Kruse, 2/c, Vice-Chairman of the branch, presided.

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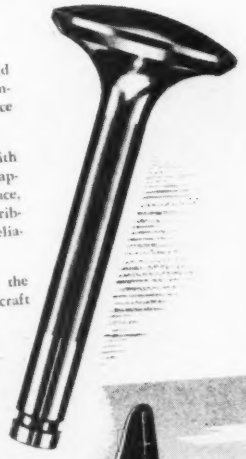

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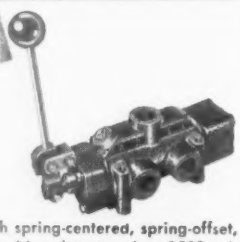

4-way valves with spring-centered, spring-offset, and 1, 2, or 3 position detent action. 1500 psi. Flows to 28 gpm.

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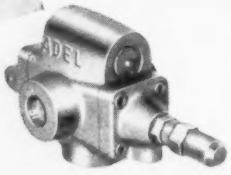

Relief, Sequence and Unloading valves. Direct or remote operation, 50 to 1500 psi range.

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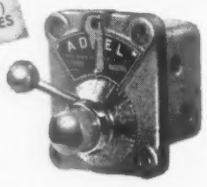

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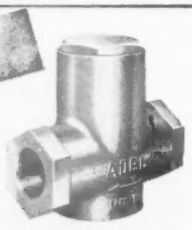

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▶ Vice-Chairman Kruse led the February 1 meeting at which 31 students were present. A U.S.N. training film, *Recognition of Jet Aircraft*, and a Department of Defense film, *Combat Bulletin—U.N. Offensive*, were shown.

▶ On February 8, with Midshipman Kruse in the chair, Lt. Col. George W. Porter, U.S.A.F., spoke on "The United States Air Force Training Program." Colonel Porter is an Instructor in the Department of Aviation, U.S. Naval Academy. Thirty-nine students were present.

Virginia Polytechnic Institute

With approximately 60 students in attendance at the February 21 meeting, Melvin N. Gough, Chief, Flight Research Division, N.A.C.A., Langley Air Force Base, Va., spoke on "The Use of Piloted Aircraft in Aeronautical Research." Two untitled films on vortex patterns were shown along with a third film entitled *Flight Tests at Muroc*. Chairman Elden S. Cornette presided.

University of Wichita

On December 20, Dick Taylor, Project Test Pilot at the Wichita Division, Boeing Airplane Company, spoke on the "Organization and Purpose of the B-47 Flight Test Program." Vice-Chairman Donald D. Hufford presided; 8 persons were present.

Members Elected

The following applicants for membership or applicants for change of previous grades have been admitted since the publication of the list in the last issue of the REVIEW.

Elected to Associate Fellow Grade

Smith, Deryck C., M.A., Technical Asst. to Secretary, Royal Aero. Society.

Transferred to Associate Fellow Grade

Ariessohn, Arthur M., M.A. (Math.), Sr. Aerodynamics Engineer, Consolidated Vultee Aircraft Corporation (San Diego).

Bergrun, Norman R., B.S. in A.E. & M.E., Research Engineer, Ames Aero. Lab., N.A.C.A.

Ganzer, Victor M., B.S. in Ae.E., Associate Professor of Aero. Engineering, University of Washington.

Goldin, Robert, M.S., Head, Criteria & Loads Section, Structures Dept., Bell Aircraft Corp.

Hage, Robert E., M.S. in Ae.E., Preliminary Design Project Engineer, Boeing Airplane Co. (Seattle).

Lemonier, Camille R., M.E., Chief Engineer, Fairchild Guided Missiles Div., Fairchild Engine & Airplane Corp.

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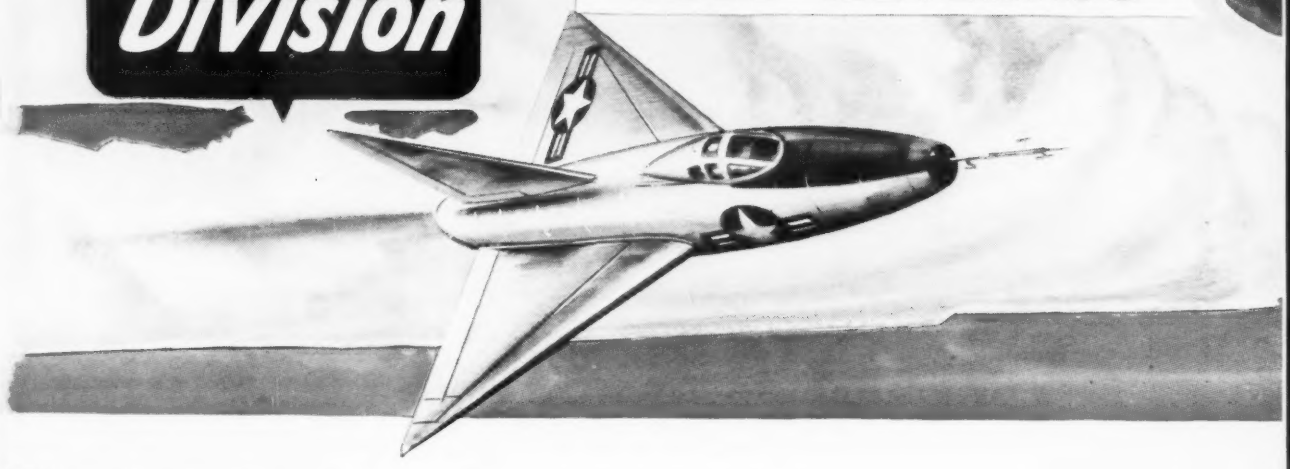

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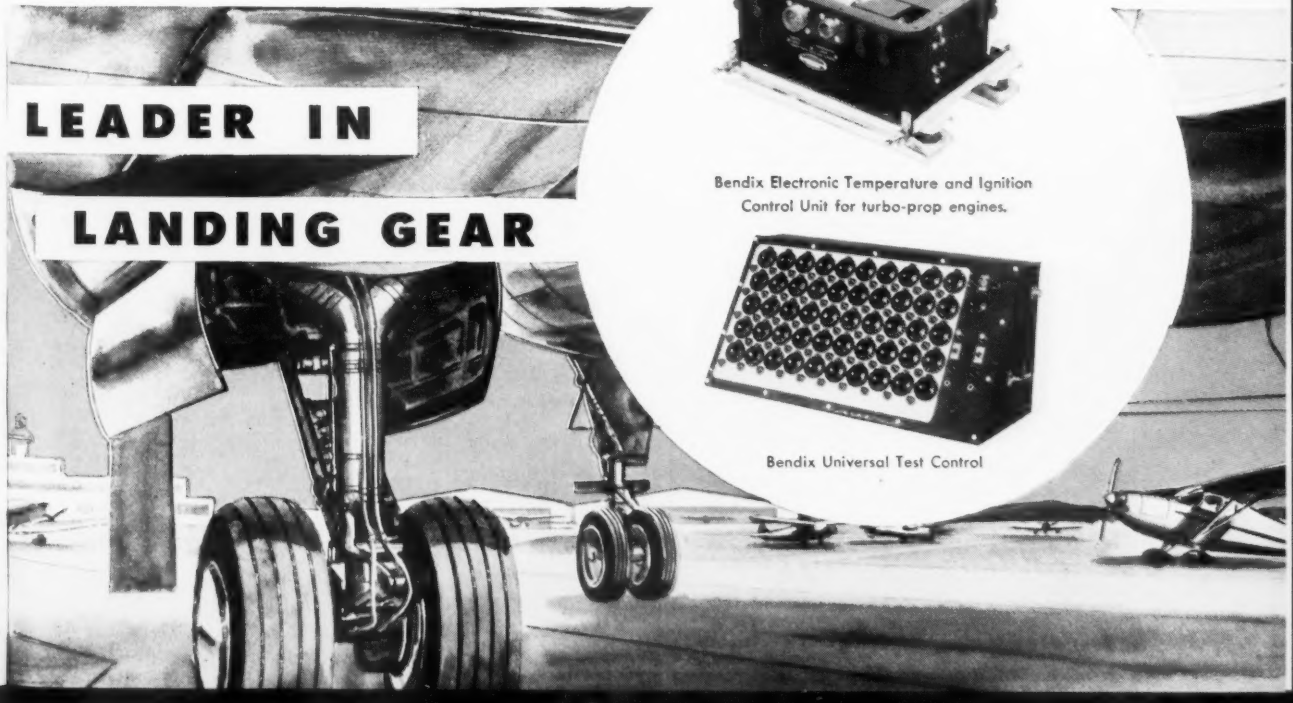

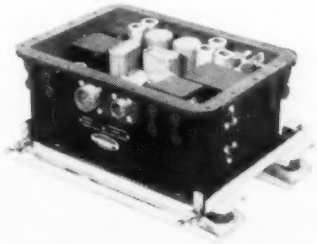

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  - Cable clamps
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  - Stripping
  - Tinning
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  - Large contacts
  - Small contacts
- Assembly
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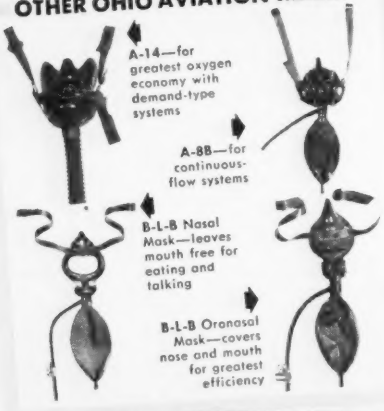
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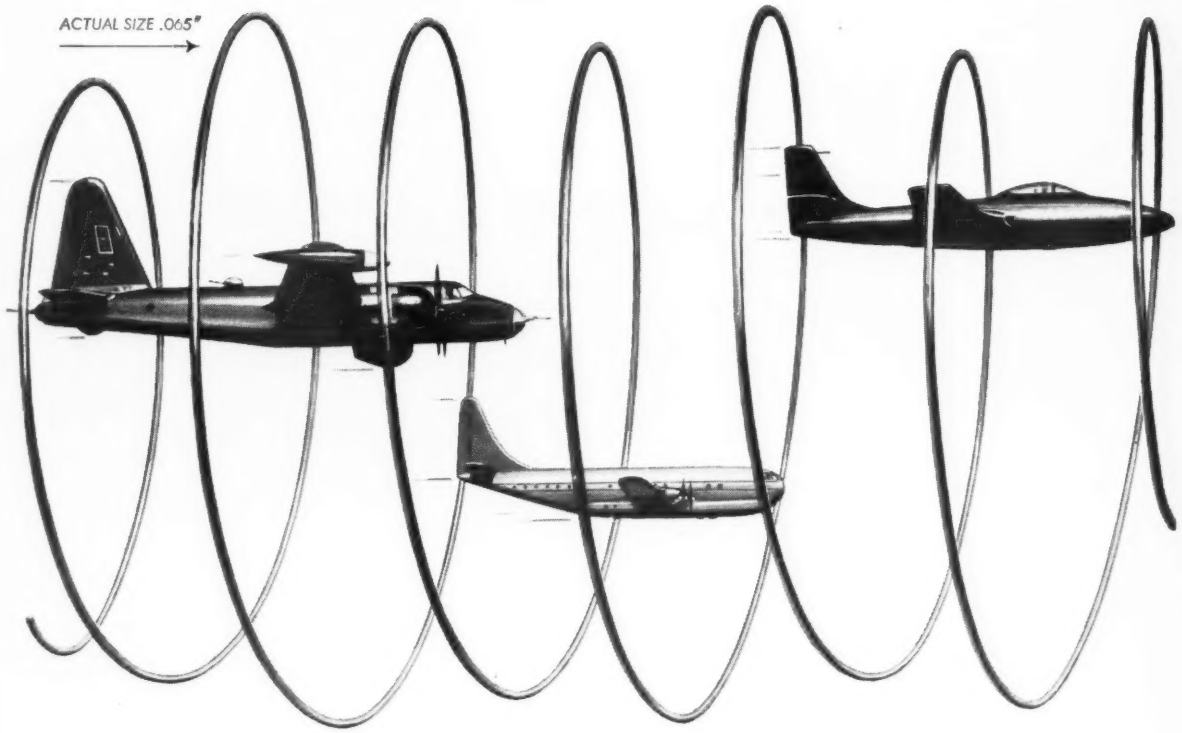

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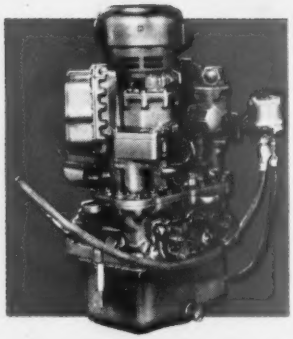

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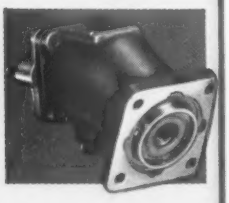

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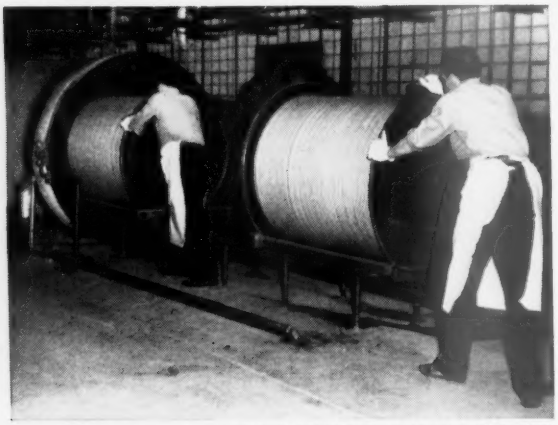

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Aerodynamics (2)

BOUNDARY LAYER & THERMOAERODYNAMICS

Effect of Slip on Flow near a Stagnation Point and in a Boundary layer. T. C. Lin and S. A. Schaaf. *U.S., N.A.C.A., Technical Note No. 2568*, December, 1951. 28 pp., illus. 19 references. Theoretical determination of the rarefaction effect of slip near a stagnation point in the boundary layer on a flat plate, using the Navier-Stokes differential equations.

Mechanism of Automatic Trailing Edge Suction. August Raspet. *Mississippi State College, Engineering Research Station, Research Report No. 1* [*U.S., Office of Naval Research, Contract Nonr 223(00)*] December 31, 1951. 32 pp., illus. 23 references.

Investigation of boundary-layer stabilization by means of trailing-edge suction in free-flight tests on a TG-3A sailplane equipped with a test section 45 in. wide and 60-in. chord length of an NACA 4416 airfoil with a trailing-edge slot; examination of the mechanism of trailing-edge suction; optimum location of the suction slot; evaluation of a porous laminar boundary-layer stabilization method.

Boundary Layer Control by Suction. *Shell Aviation News*, No. 161, November, 1951, pp. 11–13, illus.

Boundary-layer control tests, at N.A.C.A.'s Langley Aeronautical Laboratory, with suction along a skin of porous metal on the leading edges of the wings of an aircraft in actual flight.

Boundary-Layer Control. A. G. Thomson. *Flight*, Vol. 61, No. 2241, January 4, 1952, pp. 19, 20, illus. Basic considerations; research techniques; summary of results obtained to date.

Stability of the Compressible Laminar Boundary Layer with an External Pressure Gradient. J. A. Laurmann. *College of Aeronautics, Cranfield, England, Report No. 48*, September, 1951. 79 pp., illus. 23 references. 5*s*. Extension of the small perturbation theory of the stability of the laminar boundary layer to compressible flow with a pressure gradient in the main stream.

Descent from Satellite Orbits Using Aerodynamic Braking. T. Nonweiler. *British Interplanetary Society, Journal*, Vol. 10, No. 6, November, 1951, pp. 258–274, illus.

Theoretical analysis of the descent of a piloted aircraft from a circular orbit through the atmosphere, considering chiefly the problem of surface heating caused by air friction; summary of results of studies on various aspects of the heat-transfer problem at high speeds; investigation of wing-loading criteria and the effect of wing area on the surface temperature of the aircraft.

Investigation of Laminar Boundary Layer in Compressible Fluids Using the Crocco Method. E. R. Van Driest. *U.S., N.A.C.A., Technical Note No. 2597*, January, 1952. 78 pp., illus. 4 references.

CONTROL SURFACES

Theoretical Analysis of Some Simple Types of Acceleration Restrictors. William H. Phillips. *U.S., N.A.C.A., Technical Note No. 2574*, December, 1951. 35 pp., illus. 3 references.

An analysis of acceleration restrictors that operate on the principle of stopping the upward motion of the elevator when the signal from an acceleration-sensing device reaches a certain value, based on calculations for a representative fighter and a transport aircraft at sea level and at 40,000 ft. at three c.g. positions.

Effect of Various Parameters Including Mach Number on the Single-Degree-of-Freedom Flutter of a Control Surface in Potential Flow. Harry L. Runyan. *U.S., N.A.C.A., Technical Note No. 2551*, December, 1951. 33 pp., illus. 12 references.

FLUID MECHANICS & AERODYNAMIC THEORY

A Direct Aerodynamic Proof of the Biot-Savart Law. J. Lockwood Taylor. *The Aeronautical Quarterly*, Vol. 3, Part 3, November, 1951, pp. 238, 239.

Flow Rate Conversion Chart. Nils M. Sverdrup. *Product Engineering*, Vol. 22, No. 12, December, 1951, p. 197.

General Consideration of Problems in Compressible Flow Using the Hodograph Method. Chieh-Chien Chang. *U.S., N.A.C.A., Technical Note No. 2582*, January, 1952. 113 pp., illus. 77 references.

Investigation of the hodograph method as it is applied in general to compressible flow problems. Canonical and other forms of differential equations are derived for subsonic, transonic, and supersonic flows; solutions are given for the canonical forms of the approximate differential equations. Chaplygin's second differential equation is developed in detail, along with the transformations between the hodograph and physical planes. This approximate method is compared with results obtained by an exact method for the case of the flow of a compressible fluid through an aperture of a two-dimensional inclined-wall, straight-edged nozzle.

On Virtual Mass and Transient Motion in Subsonic Compressible Flow. John W. Miles. *Quarterly Journal of Mechanics and Applied Mathematics*, Vol. 4, Part 4, December, 1951, pp. 388–400, illus. 10 references.

Analysis of the transient motion of a body in a compressible fluid, based on the acoustic approximation, to show the limits of the applicability of the concept of virtual mass. That this concept applies only to steady flow is shown by a study of the transient motion of a circular cylinder at low subsonic speeds in an ideal compressible fluid for cases of a suddenly applied force and a suddenly imparted velocity; the importance of the dissipation of energy (radiation) is also investigated.

A New Variational Principle for Isenergetic Flows. C. C. Lin. *Quarterly of Applied Mathematics*, Vol. 9, No. 4, January, 1952, pp. 421–424. 1 reference.

Approximate Methods for Calculating the Flow About Nonlifting Bodies of Revolution at High Supersonic Airspeeds. A. J. Eggers, Jr., and Raymond C. Savin. *U.S., N.A.C.A., Technical Note No. 2579*, December, 1951. 40 pp., illus. 10 references.

Development of explicit expressions that provide the Mach Number and pressure distributions about pointed nonlifting bodies of revolution operating at high supersonic air speeds, by means of a theory that treats the flow in two parts: the flow at the vertex and the flow downstream of the vertex; application to the case of flow about cones over a free-stream Mach Number range of 1 to 15.

Compressibility Corrections for Bodies of Revolution. Boris A. Rabineau. *Journal of the Aeronautical Sciences*, Vol. 19, No. 3, March, 1952, pp. 197–200, 206, illus. 4 references.

Development of a formula that gives the effect of compressibility for any Mach Number, taking into account the general body shape. The formula is valid for bodies of revolution that have cylindrical center sections and is used in applying the Prandtl-Goethert rule for obtaining the influence of compressibility in axially symmetric flow about bodies of revolution. Compressibility corrections calculated by this formula are compared with experimental data.

Orientation of Orifices on Bodies of Revolution for Determination of Stream Static Pressure at Supersonic Speeds. Morton Cooper and Clyde V. Hamilton. *U.S., N.A.C.A., Technical Note No. 2592*, January, 1952. 26 pp., illus. 6 references.

Analysis of experimental data obtained on a parabolic body of revolution of large fineness ratio at $M = 1.59$ and $R = 3.6 \times 10^6$ to locate positions at which static-pressure orifices will indicate the stream static pressure independent of the pitch-yaw attitude of the body.

An Expansion Formula for the Drag on a Circular Cylinder Moving Through a Viscous Fluid at Small Reynolds Numbers. S. Tomotika and T. Aoi. *Quarterly Journal of Mechanics and Applied Mathematics*, Vol. 4, Part 4, December, 1951, pp. 401–406, illus. 4 references.

A Preliminary Study of Reynolds Number Effects on Base Pressure at $M = 2.95$. Seymour M. Bogdonoff. *Journal of the Aeronautical Sciences*, Vol. 19, No. 3, March, 1952, pp. 201–206, illus. 1 reference. Results of tests, in smooth flow and in transition, on a simple cone-cylinder body of revolution at $M = 2.95$ over a Reynolds Number range of $0.6–18 \times 10^6$.

INTERNAL FLOW

A Theory of the Direct and Inverse Problems of Compressible Flow past Cascade of Arbitrary Airfoils. Chung-Hua Wu and Curtis A. Brown. *Journal of the Aeronautical Sciences*, Vol. 19, No. 3, March, 1952, pp. 183–196, illus. 25 references.

An Analytical Investigation Using Aerodynamic Limitations of Several Designs of High Stage Pressure Ratio Multistage Compressors. Charles H. Voit and Arthur R. Thomson. *U.S., N.A.C.A., Technical Note No. 2589*, December, 1951. 56 pp., illus. 3 references.

The effect of the principal design variables on the stagewise design-point characteristics of axial-flow compressors having high

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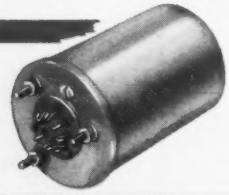

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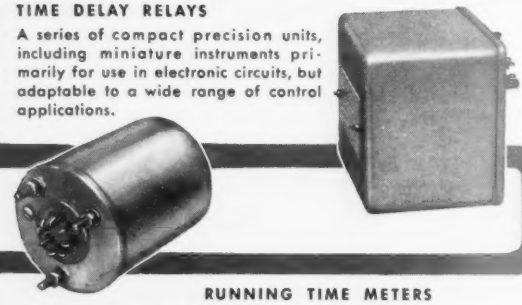

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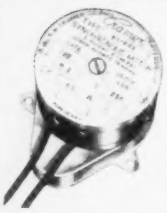

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average stage pressure ratios was analyzed to determine how close commercial compressors for turboprop and turbojet engines are to the practical limit of stage total-pressure ratios.

An Analysis of Flow in Rotating Passage of Large Radial-Inlet Centrifugal Compressor at Tip Speed of 700 Feet Per Second. Vasily D. Prian and Donald J. Michel. *U.S., N.A.C.A., Technical Note No. 2584*, December, 1951. 46 pp., illus. 4 references.

Adaptation of an approximate method of determining velocities on impeller blades to a 48-in. radial-inlet centrifugal impeller. Diagrams present theoretically predicted and experimentally corrected flow characteristics along the blade faces and throughout the passage of the impeller.

Experimental Investigation of an 0.8 Hub-Tip Radius-Ratio, Nontwisted-Rotor-Blade Turbine. David H. Silvern and William R. Slivka. *U.S., N.A.C.A., Research Memorandum No. E51G14*, December 12, 1951. 18 pp., illus. 5 references.

Successive tests on an 0.8 hub-tip radius-ratio, nontwisted-rotor-blade turbine in combination with twisted stator blades designed to maintain zero rotor-inlet incidence angles at all radii and with nontwisted stator blades designed to maintain zero rotor-inlet incidence angles at the mean radius only; performance data for a range of equivalent, mean blade speeds from 350 to 800 ft. per sec. and stagnation pressure ratios from 1.75 to 4.0.

A Note on the Design of Ducted Fans. Bryan Thwaites. *The Aeronautical Quarterly*, Vol. 3, Part 3, November, 1951, pp. 173–180.

A solution in which strip theory equations are adapted so that design for a given performance and performance for a given fan can be calculated in one direct step; conditions for maximum efficiency.

Design of Two-Dimensional Channels with Prescribed Velocity Distributions Along the Channel Walls. II—Solution by Green's Function. John D. Stanitz. *U.S., N.A.C.A., Technical Note No. 2595*, January, 1952. 35 pp., illus. 5 references.

Flow Through Uniformly Tapped Pipes. B. G. van der hegge Zijnen. *Applied Scientific Research, Section A, Mechanics, Heat, Chemical Engineering, Mathematical Methods*, Vol. A3, No. 2, 1951, pp. 144–162, illus. 12 references.

Review of the theory of laminar and turbulent flow through a pipe with porous walls; analysis of the problem of uniform discharge from a pipe, including the effects of variable fluid friction and of a pressure recovery less than 1.

Concerning the Flow About Ring-Shaped Cowlings. VI—Further Measurements on Inlet Devices. Dietrich Küchemann and Johanna Weber. (*ZWB, Forschungsbericht, Nr. 1236/6*, March 30, 1942.) *U.S., N.A.C.A., Technical Memorandum No. 1327*, December, 1951. 21 pp., illus. 1 reference.

Wall Effects in Cavity Flow. II. G. Birkhoff, M. Plesset, and N. Simmons. *Quarterly of Applied Mathematics*, Vol. 9, No. 4, January, 1952, pp. 413–421, illus. 5 references.

Analysis, using the technique of conformal transformation, of the flow about a cavitating body in the form of a finite lamina in an infinite stream, in a channel of finite width, and in a free jet of finite width.

PARASITIC COMPONENTS & INTERFERENCE

Influence of Wing and Fuselage on the Vertical-Tail Contribution to the Low-Speed Rolling Derivatives of Midwing Airplane Models with 45° Sweptback Surfaces. Walter D. Wolhart. *U.S., N.A.C.A., Technical Note No. 2587*, December, 1951. 55 pp., illus. 12 references.

STABILITY & CONTROL

A Theoretical Analysis of the Effect of Several Auxiliary Damping Devices on the Lateral Stability and Controllability of a High-Speed Aircraft. Ordway B. Gates, Jr. *U.S., N.A.C.A., Technical Note No. 2565*, December, 1951. 39 pp., illus. 8 references.

Automatic Flight Control—Analysis and Synthesis of Lateral-Control Problem. R. N. Bretoi. (*Instrument Society of America, Industrial Instruments and Regulators Division, Conference, Houston, Texas*, September 10–14, 1951.) *American Society of Mechanical Engineers, Industrial Instruments and Regulators Division, Paper No. 51–IIRD–1*, 1951. 13 pp., illus. 3 references.

A Comparison of Predicted and Experimentally Determined Longitudinal Dynamic Responses of a Stabilized Airplane. Louis H. Smaus, Marvin R. Gore, and Merle G. Waugh. *U.S., N.A.C.A., Technical Note No. 2578*, December, 1951. 53 pp., illus. 5 references.

An investigation, based on standard servomechanism theory, to determine how well the longitudinal dynamic stability of an autopilot²aircraft combination can be predicted from the separately measured in-flight characteristics of the autopilot and of the aircraft.

Longitudinal Stability Fundamentals. M. L. Wisniewski. *Aircraft Engineering*, Vol. 23, No. 274, December, 1951, pp. 362–367, illus. 8 references.

Outline of the fundamentals of static longitudinal stability; equations for the structure of static stability, the conditions defining standard stability, and the stability contributions of the wings, fuselage, and tail; calculation of the power effects of operating propellers and jet engines.

WINGS & AIRFOILS

A Method of Variation for Flow Problems. II. A. R. Manwell. *Quarterly of Applied Mathematics*, Vol. 9, No. 4, January, 1952, pp. 405–412. 4 references.

Development of the method of the variation of reference and extension to three-dimensional flows. In this method, it is shown how certain problems concerning airfoils having minimal properties may be reduced to the solution of integro-differential equations that determine the mapping of the airfoil onto a circular region.

Two-Dimensional Airfoils in Shear Flow. I. D. G. James. *Quarterly Journal of Mechanics and Applied Mathematics*, Vol. 4, Part 4, December, 1951, pp. 407–418. 4 references.

Mathematical development of a solution to the hydrodynamical problem of an airfoil in shear flow. The solution is applicable to both a stationary and a moving airfoil. The components of the force and couple on a cylinder are fixed at an arbitrary point in the flow field; the transformation is modified for a thin, curved airfoil and for a tapering, straight airfoil.

The Flow of Two Adjacent Plane Supersonic Jets Past Flat-Plate Wings. II. M. Holt. *Quarterly Journal of Mechanics and Applied Mathematics*, Vol. 4, Part 4, December, 1951, pp. 419–430, illus. 3 references.

The linearized method of conical fields which is used to find the disturbance in the stream from two adjacent supersonic jets due to a delta wing with its apex in the jet boundary is extended to include wings on which subsonic conditions apply along part of or the entire leading edge.

Determination of Elastic Wing Aerodynamic Characteristics. William J. Gaugh and Joseph K. Slap. *Journal of the Aeronautical Sciences*, Vol. 19, No. 3, March, 1952, pp. 173–182, illus. 10 references.

The Flow over Symmetrical Aerofoils Without Incidence in the Lower Transonic Range. Tore R. Gullstrand. *Sweden, Kungliga Tekniska Högskola, Institution för Flygteknik, Technical Note No. KTH-AERO TN 20*, August, 1951. 20 pp., illus. 4 references. In English.

Development of an iterative method for the solution of Oswatitsch's integral method for obtaining the flow around airfoils at lower transonic speeds; calculation of the velocity distribution on NACA 63A006, 64A006, and 65A006 airfoils at zero incidence for various shock-wave locations.

Transonic Flow past a Wedge Profile with Detached Bow Wave—Details of Analysis. Walter G. Vincenti and Cleo B. Wagoner. *U.S., N.A.C.A., Technical Note No. 2588*, December, 1951. 48 pp., illus. 32 references. Details of the analytical procedure for obtaining the flow with detached bow wave past a doubly symmetric, double-wedge profile at zero incidence.

Readers' Forum: Pressure Distribution on an Airfoil in Nonuniform Motion. S. Neumark. *Journal of the Aeronautical Sciences*, Vol. 19, No. 3, March, 1952, pp. 214, 215. 5 references.

The Profile Drag of Yawed Wings of Infinite Span. A. D. Young and T. B. Booth. *The Aeronautical Quarterly*, Vol. 3, Part 3, November, 1951, pp. 211–229, illus. 10 references.

Development of a method for calculating the profile drag of a yawed wing of infinite span. The form of the spanwise velocity distribution in the boundary layer is assumed to be insensitive to the chordwise pressure distribution; its form is identical with the form of the boundary layer on an unyawed plate having zero external pressure gradient. Calculations are compared with experimental data. The method is illustrated by calculating the drag of a flat plate and of an NACA 64-012 airfoil at zero angle of attack for $R = 10^6$–10^8, yaw angles up to 45°, and a range of transition point positions.

Wind-Tunnel Tests at Low Speed of Swept and Yawed Wings Having Various Plan Forms. Paul E. Purser and M. Leroy Spearman. (*U.S., N.A.C.A., Research Memorandum No. L7D23.*) *U.S., N.A.C.A., Technical Note No. 2445*, December, 1951. 82 pp., illus. 15 references.

A New Approach to Thin Aerofoil Theory. M. J. Lighthill. *The Aeronautical Quarterly*, Vol. 3, Part 3, November, 1951, pp. 193–210. 7 references.

Analysis of the two-dimensional, irrotational, incompressible flow over thin wings with rounded leading edges, based on a general technique of rendering approximate solutions to physical problems uniformly valid; possibilities of extending the method to three-dimensional compressible flow. The series expansion of the velocity field is modified by introducing, with each approximation, a slight straining of the coordinate system. This straining is determined progressively to ensure uniform convergence near the leading edge. The Kutta-Joukowsky condition is applied at the trailing edge.

Experimental Investigation of Rolling Performance of Straight and Sweptback Flexible Wings with Various Ailerons. Henry A. Cole, Jr., and Victor M. Ganzer. *U.S., N.A.C.A., Technical Note No. 2563*, December, 1951. 45 pp., illus. 8 references.

Pitching-Moment Derivatives C_{m_q} and $C_{m_{\dot{\alpha}}}$ at Supersonic Speeds for a Slender-Delta-Wing and a Slender-Body-Combination and Approximate Solutions for Broad-Delta-Wing and Slender-Body Combinations. Arthur Henderson, Jr. *U.S., N.A.C.A., Technical Note No. 2553*, December, 1951. 29 pp., illus. 14 references.

Aeroelasticity

A Flight Investigation of the Effect of Center-of-Gravity Location on Gust Loads. Jack Funk and Earle T. Binckley. *U.S., N.A.C.A., Technical Note No. 2575*, December, 1951. 18 pp., illus. 8 references.

Calculations on the Forces and Moments for an Oscillating Wing-Aileron Combination in Two-Dimensional Potential Flow at Sonic Speed. Herbert C. Nelson and Julian H. Berman. *U.S., N.A.C.A., Technical Note No. 2590*, January, 1952. 36 pp., illus. 8 references.

Control Surface Flutter. I—Theory. II—Practice. E. G. Broadbent and W. T. Kirby. *The Aeroplane*, Vol. 81, Nos. 2109, 2112, December 21, 1951, January 11, 1952, pp. 785–787, 39–41, illus. *Flight*, Vol. 61, Nos. 2242, 2243, January 11, 18, 1952, pp. 45–48, 75–77, illus.

Readers' Forum: Single Degree of Freedom Flutter of an Aileron. H. L. Runyan, H. J. Cunningham, and C. E. Watkins. *Journal of the Aeronautical Sciences*, Vol. 19, No. 3, March, 1952, pp. 215, 216. 5 references.

Some Effects of Variations in Several Parameters Including Fluid Density on the Flutter Speed of Light Uniform Cantilever Wings. Donald S. Woolston and George E. Castile. *U.S., N.A.C.A., Technical Note No. 2558*, December, 1951. 40 pp., illus. 6 references.

Readers' Forum: Generalization of the Theodorsen Function to Stable Oscillations. A. I. Van de Vooren. *Journal of the Aeronautical Sciences*, Vol. 19, No. 3, March, 1952, pp. 209–211, illus. 6 references. Development of a formula valid for stable and unstable oscillations which denotes the generalization of $C(k)$ to a finite wake length.

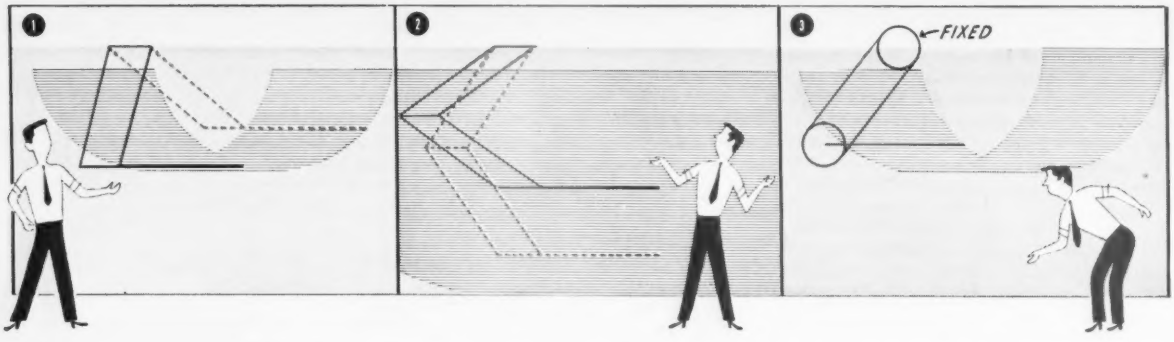
Readers' Forum: Theodorsen's Circulation Function for Generalized Motion. E. V. Laitone. *Journal of the Aeronautical Sciences*, Vol. 19, No. 3, March, 1952, pp. 211–213. 6 references.

Limitations of the application of Theodorsen's circulation function to stable damped motions; derivation of the reciprocal relations between Wagner's step-function response and Theodorsen's steady-state sinusoidal response from the lift deficiency function of von Kármán and Sears.

Readers' Forum: The Generalized Theordorsen Function. W. P. Jones. *Journal of the Aeronautical Sciences*, Vol. 19, No. 3, March, 1952, p. 213. 4 references. Definition and interpretation of the lift function, in terms of Hankel equations, for unstable motions of the type $e^{(\mu + i\omega)s}$.

Readers' Forum: Notes on the Calculation of the Response of Stable Aerodynamic Systems. M. A. Dengler, M. Goland, and Y. L. Luke. *Journal of the Aeronautical Sciences*, Vol. 19, No. 3, March, 1952, pp. 213, 214.

Mathematical proof of the validity of the use of the exponential form of the approximation of the Wagner growth-of-lift function



Start with a parallelogram somewhat like this. Visualize one of its short sides anchored to the top of a drawing board parallel to your base line, and let the remaining three sides be free to move together. Add a projecting straightedge to the bottom side as shown, and it will theoretically stay parallel to the base line. Parallel lines could be drawn anywhere within the shaded area above. But clearly, that field of action is too limited.

To obtain parallel motion over the entire working surface of the board, a second parallelogram could be coupled to the bottom of the first so that both have one short side in common. An elementary drafting machine would result . . . at least in principle. In practice, it would fall short because the slightest play at any of its 8 joints would create gross error at the straightedge.

What is needed is a better mechanical design based on the same parallelogram principle. Take a pair of rotating drums, connect them with a tight steel band, and the assembly will behave like a parallelogram if the drum diameters are equal. Now couple a second band-and-drum assembly to the first in such a way that they have the middle drum in common . . . and you have the basis of a modern drafting machine.

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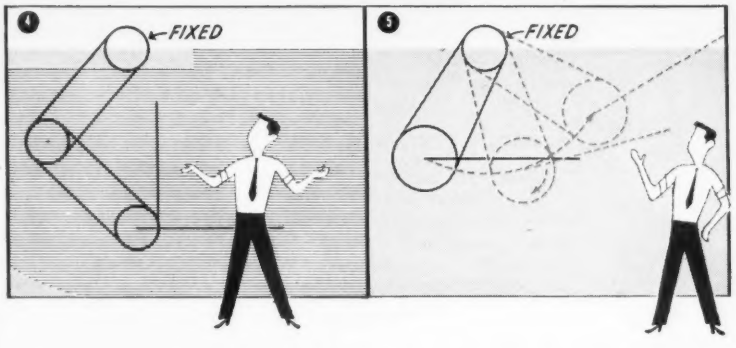

The band-and-drum machine, with all three drums of precisely equal diameters and with bands which will not slip, will draw absolutely parallel lines over the entire working area. But if the drum diameters are not equal, the parallelogram principle is violated and the machine cannot draw parallel lines. The greater the difference in diameter the more the lines will be out of parallel.

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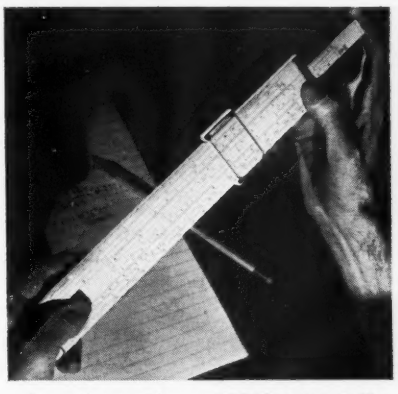

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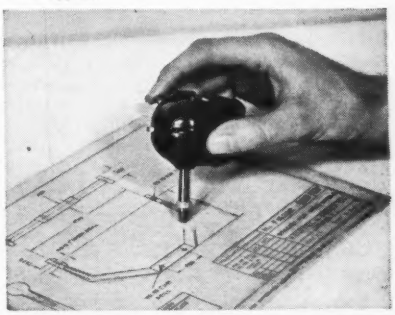

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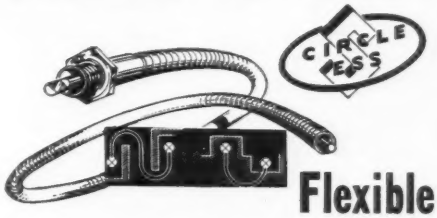

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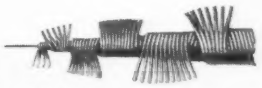

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An investigation of the behavior of the synchronous rectifier when a sine-wave input of arbitrary frequency, phase, and amplitude is impressed upon the rectifier, assuming that it inverts periodically the polarity of the input at a given fixed frequency; application to cases when the input contains nonsynchronous components; comparison of the selectivity and damping factors.

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The dielectric properties and structure of some new synthetic polymers and of other insulating materials are analyzed and compared for their suitability to instrument application; tables give the values of dielectric constants and loss angles.

Components for Instruments. R. E. Hall and E. Coop. (*I.E.E., Measurements Section, Paper No. 1155.*) *Institution of Electrical Engineers, Proceedings, Part II, Power Engineering*, Vol. 98, No. 66, pp. 738–752, Discussion, pp. 753–759, illus. 21 references. Characteristics and performance criteria for the reliability and functional suitability of components, new techniques, and materials for improving design and production.

Some Special Characteristics of Soft Magnetic Materials Used in Instrument Manufacture. G. A. V. Sowter. (*I.E.E., Measurements Section, Paper No. 1154.*) *Institution of Electrical Engineers, Proceedings, Part II, Power Engineering*, Vol. 98, No. 66, December, 1951, pp. 714–727, Discussion, pp. 753–759, illus. 7 references.

An analysis of the variation of induction and permeability with magnetizing force and of the advantages and typical instrument applications of the principal high-permeability alloys; magnetostriction; the variation of magnetic properties with temperature in some magnetic materials; comparison of their relative permeability and cost; wave-form and correlation diagrams. A method is presented for predicting the harmonic distortion in small transformers and chokes.

Germanium; Recent Progress in Its Application to Crystal Valves. T. H. Kinman. *Wireless World*, Vol. 58, No. 1, January, 1952, pp. 29, 30, illus. 6 references.

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Relationships Between Voice Variables and Speech Intelligibility in High Level Noise. G. L. Draegert. (*Speech Monographs*, Vol. 18, No. 4, November, 1951.) *Purdue University, N6ori-104, T.O. II, Project NR-782-003, Technical Report No SDC 104-2-25*, November, 1951. 7 pp., tables. 21 references. Reprint.

COMPUTERS

The Binac. A. A. Auerbach, J. P. Eckert, Jr., R. F. Shaw, J. R. Weiner, and L. D. Wilson. *Institute of Radio Engineers, Proceedings*, Vol. 40, No. 1, January, 1952, pp. 12–29, illus. 3 references. System considerations, engineering design, circuits, and operational procedure of the Binac high-speed electronic digital computer; efficiency; applications.

On the Background of Pulse-Coded Computors. I. T. J. Rey. *Electronic Engineering*, Vol. 24, No. 287, January, 1952, pp. 28–32, illus. 18 references.

Outline of computer principles; organization and storage systems of digital computers; explanation of the binary system of numbers and pulse-coding techniques using the binary system; representation of positive and negative numbers.

Logical Description of Some Digital-Computer Adders and Counters. Harry J. Gray, Jr. *Institute of Radio Engineers, Proceedings*, Vol. 40, No. 1, January, 1952, pp. 29–33, illus. 10 references.

Standard Plug-In Type Counter. Donald Eadie. *Review of Scientific Instruments*, Vol. 22, No. 11, November, 1951, p. 836, illus. Plug-in unit for use in the ENIAC and the EDVAC large-scale digital computers; it can count 40-volt, 2 μsec. pulses spaced at 1 μsec. intervals.

Super-Speed Tape Puller for Computer Memory. *Electronics*, Vol. 25, No. 1, January, 1952, pp. 222, 224, 226, illus. Magnetic tape handling machine for use with the National Bureau of Standards' SEAC computer; factors involved in the development of the tape memory mechanism.

Germanium Diode Experience. *Radio & Television News*, Vol. 47, No. 1, January, 1952, *Radio-Electronic Engineering*, pp. 20, 21, illus. Summary of a study of the performance of the 16,000 germanium diodes used for computing and switching in the National Bureau of Standards' SEAC computer.

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CONSTRUCTION TECHNIQUES

A Method of Improving the Electrical and Mechanical Stability of Point-Contact Transistors. B. N. Slade. *RCA Review*, Vol. 12, No. 4, December, 1951, pp. 651–659, illus. 2 references. The use of thermosetting resins for the embedding of point-contact transistors; embedding procedures.

Potted Circuits; New Development in Miniaturization of Equipment. *Wireless World*, Vol. 57, No. 12, December, 1951, p. 493, illus.

The Deposition of H.F. Crystal Electrodes by Vacuum Coating. L. Holland. *Electronic Engineering*, Vol. 24, No. 287, January, 1952, pp. 10–13, illus. 8 references. Design and control of a vacuum-coating apparatus for applying thin metal films to high-frequency quartz crystal plates.

High-Speed Tandem Winding Machines. Sylvan A. Wolin. *Radio & Television News*, Vol. 47, No. 1, January, 1952, pp. 45, 111, illus. Tandem paper-condenser winding machine makes possible the mass production of uniform condensers.

ELECTRONIC TUBES

Valve Cathode Life. C. C. Eaglesfield. *Wireless World*, Vol. 57, No. 12, December, 1951, pp. 505, 506, illus. 2 references.

Analysis of the growth of cathode resistance in relation to apparent deterioration in the life of different tube types. A method of eliminating resistance in circuit design involves use of permanent feedback.

Technique of Trustworthy Valves. Ernest G. Rowe. *Electrical Communication*, Vol. 28, No. 4, December, 1951, pp. 257–275, illus.

Survey of construction techniques, failure causes, and methods of testing and improving electronic tubes to achieve a service life of 1,000 hours with only 1 per cent failure; special problems connected with the production of glass tubes.

Some Effects of Vibration Within Electron Tubes. T. H. McNary. *S.A.E., Annual Meeting, Detroit, January 14–18, 1952, Preprint No. T11.* 15 pp., illus. Experimental analysis of tube structure resonance; test program and equipment.

Crystal Diodes in Modern Electronics. IV. David T. Armstrong. *Radio & Television News*, Vol. 47, No. 1, January, 1952, pp. 63–65, 127–133, illus. Application in f.m. circuits.

On the Theory of Electron Wave Tubes. Olof Rydbeck and Sven Forsgren. (*Chalmers Tekniska Högskola, Handlingar Nr. 104*, 1951.) *Acta Polytechnica* (*Stockholm*), No. 84 (*Electrical Engineering Series*, Vol. 3, No. 8), 1951. 31 pp., illus. 6 references. Sw. Kr. 3:50. In English.

An investigation of the properties of double-stream traveling wave tubes. Fundamental equations are derived for one electron beam with a strong focusing axial magnetic force. Equations are then developed for the effect of a single beam in a neutral ionized gas, the influence of the axial magnetic focusing field and the coupling of *TE* and *TM* waves, and the development of the electron beam waves on two well-mixed beams.

Circuits of the Balitron Tube. Norman Z. Ballantyne. *Radio & Television News*, Vol. 47, No. 1, January, 1952, *Radio-Electronic Engineering*, pp. 6–8, 30, 31, illus. Development, operation, and diagrams of circuits that utilize the stable negative resistance characteristic of the Balitron tube at ordinary operating voltages.

Special Tubes for Broad-Band Amplifiers. *Electronics*, Vol. 25, No. 1, January, 1952, pp. 142, 204, 208, illus. Construction of broad-band tubes that have a high ratio of transconductance to capacitance. This is achieved by a new grid that uses many turns of very fine tungsten wire.

Transmission-Line Tubes. *Electronics*, Vol. 25, No. 1, January, 1952, pp. 214, 216, 218, illus.

Construction and advantages of a tube design that makes use of the chain-amplifier principle within a single tube. The tube is of five-element (pentode) construction; this is connected at both ends to a grid wound helically about a ceramic cylinder.

Tunable Miniature Magnetron. D. A. Wilbur, P. H. Peters, and H. W. A. Chalberg. *Electronics*, Vol. 25, No. 1, January, 1952, pp. 104–109, illus.

Design, structure, and performance of a miniature magnetron for use as a local oscillator in U.H.F. receivers. It provides outputs up to 0.5 w. over a frequency range of zero to 1,000 mc.

Ground-Transmitter Klystron for Air Navigation. Vincent Learned. *Electronics*, Vol. 25, No. 1, January, 1952, pp. 136, 138, 156, 160, 165, illus.

Development of the SAX-22 klystron tube for the responder-type of ground transmitters for air navigation systems. The tube is designed for the 9,300-mc. frequency region with a power output between 5 and 20 kw. A small diameter electron beam is used to avoid the use of a grid and to provide high power outputs.

An Experimental High-Transconductance Tube Using Space-Charge Deflection of the Electron Beam. J. T. Wallmark. *Institute of Radio Engineers, Proceedings*, Vol. 40, No. 1, January, 1952, pp. 41–48, illus. 13 references.

Principles of operation and mathematical theory of an amplifier tube that uses an electron beam whose current (and therefore its space charge) is controlled by a conventional grid. The controlled space charge displaces the beam from its space-charge-free path; the beam displacement is converted, by means of a fixed intercepting edge, into additional current variation at the anode. An experimental model of the tube is evaluated.

Electronic Flash Photography. R. L. Aspden. *Aircraft Engineering*, Vol. 23, No. 274, December, 1951, pp. 354–360, illus.

Characteristics, construction, and principles of operation of the various types of electronic flash tubes used in the development, instrumentation, and operation of aircraft: basic tube control circuits.

A Note on the Temperature Coefficients of Running Voltage of Glow-Discharge Tubes. F. A. Benson and H. Bache. *Journal of Scientific Instruments*, Vol. 29, No. 1, January, 1952, pp. 25, 26. 8 references.

Obtaining Bias Voltages in Triode Vacuum Tubes. Ralph B. Immel. *Product Engineering*, Vol. 22, No. 12, December, 1951, pp. 148, 149, illus. Circuits for obtaining five types of bias voltages; input and output voltage patterns.

MEASUREMENTS & TESTING

An Improved Creep Measuring and Recording System. J. W. Huffman. *Product Engineering*, Vol. 23, No. 1, January, 1952, pp. 172–174, illus. 2 references.

Construction, operation, and advantages of a system that uses linear variable differential transformers (*LVDT*) to measure creep and a modified potentiometer recorder to chart it. Basic circuits of the *LVDT* system are shown, and the performance is compared with that of the dial indicator and cantilever strain gage creep measuring and recording systems.

RTMA Screen Phosphors. *The Oscillographer*, Vol. 12, No. 4, October–December, 1951, pp. 3–6, illus. A review of the characteristics of standard RTMA phosphors and their application as screen material in oscillography; table of screen types.

Counting-Rate Meters. G. D. Smith. *Electronic Engineering*, Vol. 24, No. 287, January, 1952, pp. 14–18, illus. 17 references.

Principles of operation of ratemeters that give approximate measurements of the counting rate; circuits for pulse-shaping; integrating, smoothing, and averaging circuits of the ratemeter; comparison of ratemeter performance with that of a scaling unit.

Tiny Pick-Up Aids Convair Study. Bill Chana. *Aviation Week*, Vol. 56, No. 1, January 7, 1952, pp. 38, 40, illus. A subminiature pressure transducer, for measuring hull bottom water pressures during take-off and landing which is used for design studies at Convair.

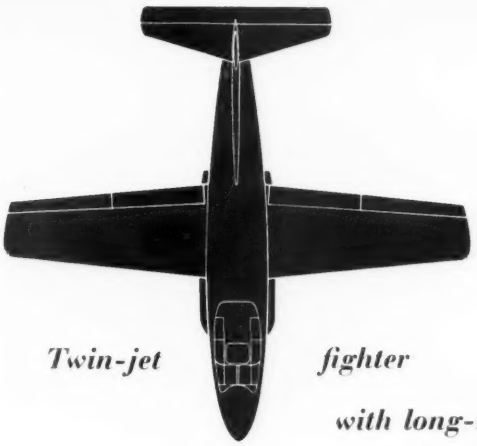
Valve Voltmeter Without Calibration Drift. M. G. Scroggie. *Wireless World*, Vol. 58, No. 1, January, 1952, pp. 14–18, illus. Theory, design, and operation of an adaptor with almost-infinite input impedance and almost-zero output resistance for use with a d.c. voltmeter; circuit diagrams.

Instruments for Use in the Microwave Band. A. F. Harvey. (*I.E.E., Measurement Section, Paper No. 1156.*) *Institution of Electrical Engineers, Proceedings, Part II, Power Engineering*, Vol. 98, No. 66, pp. 781–789, Discussion, pp. 789–792, illus. 35 references. Characteristics, operation, and design of instruments for measuring power, frequency, and impedance in the microwave band; production techniques and their influence on instrument behavior and design.

Wideband Pre-Amplifier for Atmospheric Noise Measurement. F. Horner. *Wireless Engineer*, Vol. 29, No. 340, January, 1952, pp. 19–26, illus. 2 references.

Quartz-Crystal Measurement at 10 to 180 Megacycles. E. A. Gerber. *Institute of Radio Engineers, Proceedings*, Vol. 40, No. 1, January, 1952, pp. 36–40, illus. 3 references.

Principles of operation, circuit, and correction functions of a method for measuring the equivalent parameters of the mean and spurious modes of very high-frequency crystal units.



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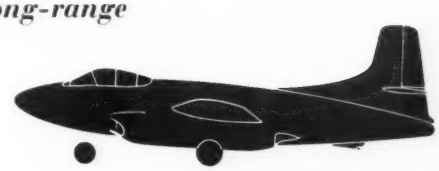

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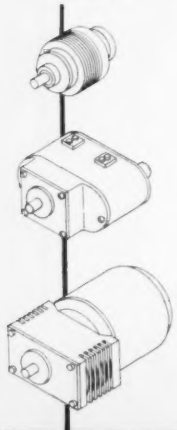

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A Self-Interpolating Crystal Calibrator for Setting Up and Measuring Radio Frequencies. D. Cooke. *Electronic Engineering*, Vol. 24, No. 287, January, 1952, pp. 23–25, illus.

Electronic Timers. E. A. Demonet and L. C. Bower. *Instruments*, Vol. 24, No. 12, December, 1951, pp. 1439–1441, 1474, illus.

Basic circuits and operation of timers with hot-cathode high-vacuum tubes and cold-cathode gas tubes for responding to signals or producing them; curves for the rapid selection of *RC* values for any required timing operation within a given tube.

NAVIGATION AIDS

Dynamic Aspect of Errors in Radio Navigation Systems Particularly in Cases of Fast Moving Receivers or Transmitters. H. Busignies. *Institute of Navigation, Journal*, Vol. 3, Nos. 1, 2, September–December, 1951, pp. 60–62, illus. 2 references. Analysis of the errors introduced into radio navigation systems in free space due to reflections from the earth's surface.

From Take-Off to Touch-Down; Operational Merits of the (Sperry) Zero Reader. *Sperry Review*, Vol. 3, No. 4, Autumn, 1951, pp. 13–17, illus.

The Decca Flight Log. M. R. Aries. *Guild of Air Pilots and Air Navigators, Journal*, Vol. 11, No. 6, December, 1951, pp. 7–9, 11–13, illus. Components and operation of the Decca Mark 7 Flight Log; advantages and limitations of the equipment.

Loran Navigation Tables. *U.S., National Bureau of Standards, Technical News Bulletin*, Vol. 36, No. 2, February, 1952, pp. 19, 20, illus. Preparation and method of using Loran navigation tables.

Airline Radio. *Shell Aviation News*, No. 162, December, 1951, pp. 4–6, illus. Review of the development of B.O.A.C.'s radio and radar equipment and maintenance systems; postwar design, construction, and testing techniques.

The Comet's Radio. *The Aeroplane*, Vol. 82, No. 2113, January 18, 1952, pp. 74–78, illus. Details of the radio equipment of the de Havilland Comet jet transport; submerged antenna installations.

AF Base Uses Homemade Homer. *Aviation Week*, Vol. 56, No. 3, January 21, 1952, p. 39, illus.

Design details of a cylindrical parabolic homing antenna with closed ends which makes contact with planes over a radius of up to 150 miles, depending upon the flight altitude. The antenna was built and installed at Columbus Air Force Base, Miss.

Brown Boveri Transmitters in the Service of Civil Aviation. A. Vincre. *Brown Boveri Review*, Vol. 38, No. 7–8, July-August, 1951, pp. 220–226, illus.

Transmitters and transmitting techniques used in the French government's transmitting center for improving meteorological service to air lines and in the center operated by Air France for communicating with traffic centers overseas.

The V.H.F. Omni-Range. Ernst Kramer. *Interavia*, Vol. 6, No. 12, 1951, pp. 682–684, illus. 2 references. Operation and equipment of a network of 8 V.O.R. installations that are under construction in Western Germany.

NOISE & INTERFERENCE

On the Distribution of Energy in Noise- and Signal-Modulated Waves. I—Amplitude Modulation. David Middleton. *Quarterly of Applied Mathematics*, Vol. 9, No. 4, January, 1952, pp. 337–354, illus. 20 references.

Results of analyses of a carrier wave amplitude-modulated by normal random noise and by a combination of a signal and a noise, and of a carrier wave simultaneously amplitude- and angle-modulated by a noise. Expressions are obtained for the mean total, continuum, and carrier powers, and for the mean power in the discrete portion of the spectrum. The spectral distribution of the wave's energy is studied in detail.

Noise Measurements on a Traveling Wave Tube. Bertil N. Agdur and Carl-Gösta L. Åsdal. (*Chalmers Tekniska Högskola, Handlingar Nr. 106*, 1951.) *Acta Polytechnica* (*Stockholm*), No. 86 (*Electrical Engineering Series*, Vol. 3, No. 10), 1951. 12 pp., illus. 4 references. Sw. Kr. 2:00. In English.

Measurements of noise and of the noise factor as a function of a beam current, carried out on a traveling wave tube with a frequency of about 10,000 mc.; comparison with current theoretical predictions.

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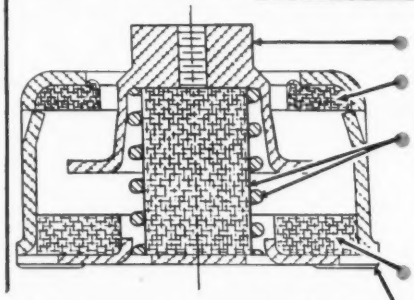

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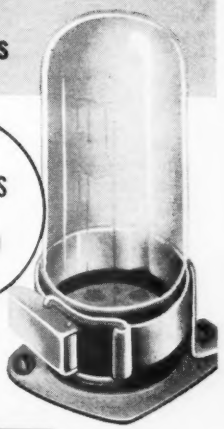

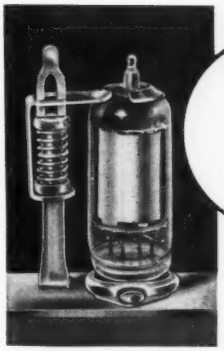

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Traveling-Wave Tube Noise Figure. D. A. Watkins. *Institute of Radio Engineers, Proceedings*, Vol. 40, No. 1, January, 1952, pp. 65–70, illus. 8 references.

Analysis of the effect of space charge and circuit loss upon the traveling-wave tube noise figure, based on the use of Hahn-Ramo space-charge waves and Peirce's theory; optimum location of the traveling-wave tube circuit entrance with respect to space-charge waves for minimum noise.

Noise Suppression in Triode Amplifiers. II. A. van der Ziel. *Canadian Journal of Technology*, Vol. 29, No. 12, December, 1951, pp. 540–553, illus. 5 references.

Experimental verification of a feedback triode circuit that theoretically gives a noise factor close to unity. The feedback circuit consists of a grounded cathode circuit with an untuned anode-grid capacity in which an additional feedback capacity is inserted in parallel.

Ionospheric Thermal Radiation at Radio Frequencies. J. L. Pawsey, L. L. McCready, and F. F. Gardner. *Journal of Atmospheric and Terrestrial Physics*, Vol. 1, No. 5–6, 1951, pp. 261–277, illus. 6 references.

Equipment, procedure, and results of a study in which man-made noise and atmospherics are minimized so that radio noise due to ionospheric thermal radiation can be identified and measured. A method is developed for measuring the electron temperature in the absorbing and emitting part of the ionosphere which at radio frequencies is at a height of about 70 or 80 km.

A Generator of Electrical Noise. Arnold P. G. Peterson. *General Radio Experimenter*, Vol. 26, No. 7, December, 1951, pp. 1–9, illus. 18 references.

Circuits, output characteristics, and applications of the General Radio Type 1390-A Random-Noise Generator. The generator uses a gas-discharge tube as the noise source; noise bands can be obtained at frequencies of 20 and 50 kc. and at 5 mc.

RADAR

Introduction to Radar Techniques. I, II, III. *Aerovox Research Worker*, Vol. 21, Nos. 10, 11, 12, October, November, December, 1951, pp. 1–3; 1–3; 1–3, illus.

I. Basic principles of radar system operation and design; limits of radar performance. **II.** Theory of the operation of the magnetron transmitting tube that is used as the high-power radio-frequency generator of a microwave radar system. **III.** Circuits and theory of pulse modulation techniques that are used to generate the high-voltage d.c. pulses that are applied to the magnetron; comparison of the performance characteristics of "hard tube" and thyratron modulators.

SATURABLE REACTORS

Magnetic Amplifier Voltage Regulator. *Electronics*, Vol. 25, No. 1, January, 1952, pp. 140, 142, illus.

Circuits and construction of a magnetic amplifier that is capable of regulating 140 to 400 volts with an accuracy of ±0.5 per cent for load currents from 0 to 500 milliamperes with line voltage constant.

The Use of Selenium Rectifiers in Self-Saturating Magnetic Amplifiers. J. R. Conrath. *Electrical Engineering*, Vol. 71, No. 1, January, 1952, pp. 51–54, illus.

Analysis of the influence of selenium rectifiers on the operation of self-saturating magnetic amplifiers; factors affecting the selection of rectifiers and of a rectifier stack for an amplifier.

TRANSMISSION LINES

Fourier Transforms in the Theory of Inhomogeneous Transmission Lines. Folke Bolinder. (*Kungliga Tekniska Högskola, Handlingar Nr. 48*, 1951.) *Acta Polytechnica* (*Stockholm*), No. 88 (*Electrical Engineering Series*, Vol. 3, No. 12), 1951. 84 pp., illus. 33 references. Sw. Kr. 6:00. In English.

A new approximate treatment, based on Fourier transforms, of inhomogeneous transmission lines is developed and compared with aerial and pulse theories. A natural law is indicated that is equivalent to the uncertainty relation of Heisenberg and is shown to govern the problem of broad banding.

Correlation of the Faraday and Kerr Magneto-Optical Effects in Transmission-Line Terms. C. H. Luhrs. *Institute of Radio Engineers, Proceedings*, Vol. 40, No. 1, January, 1952, pp. 76–78, illus. 10 references.

Circular Wave Guide Attenuation. *Radio & Television News*, Vol. 47, No. 1, January, 1952, *Radio-Electronic Engineering*, p. 32. Nomograph for determining the attenuation of the $TF_{1,1}(H_0)$ mode in a circular air-dielectric wave guide.

A Reflectionless Wave-Guide Termination. Rodney E. Grantham. *Review of Scientific Instruments*, Vol. 22, No. 11, November, 1951, pp. 828–834, illus. 6 references.

Analysis and equations for a termination design that operates over wide frequency range and uses a tunable sliding load in which the load-reflection coefficient can be adjusted to zero. The termination is used as a reference standard for microwave impedance bridges, and it eliminates mismatch errors.

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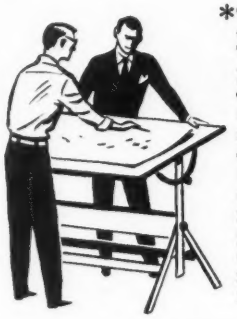

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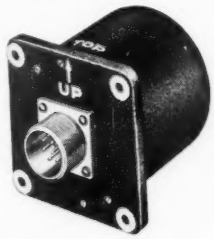

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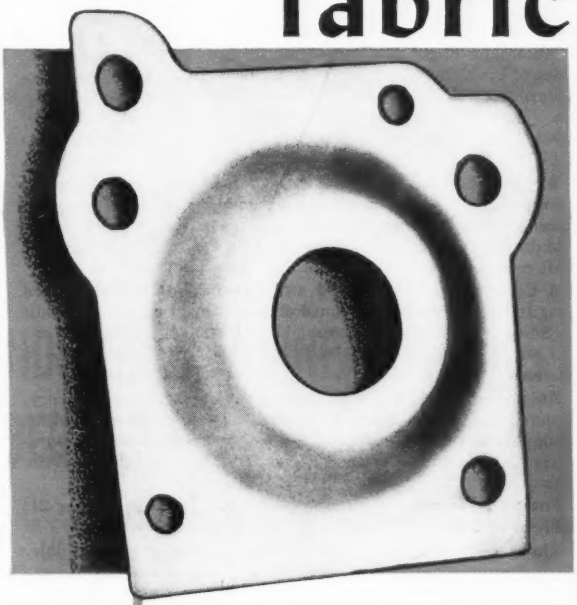

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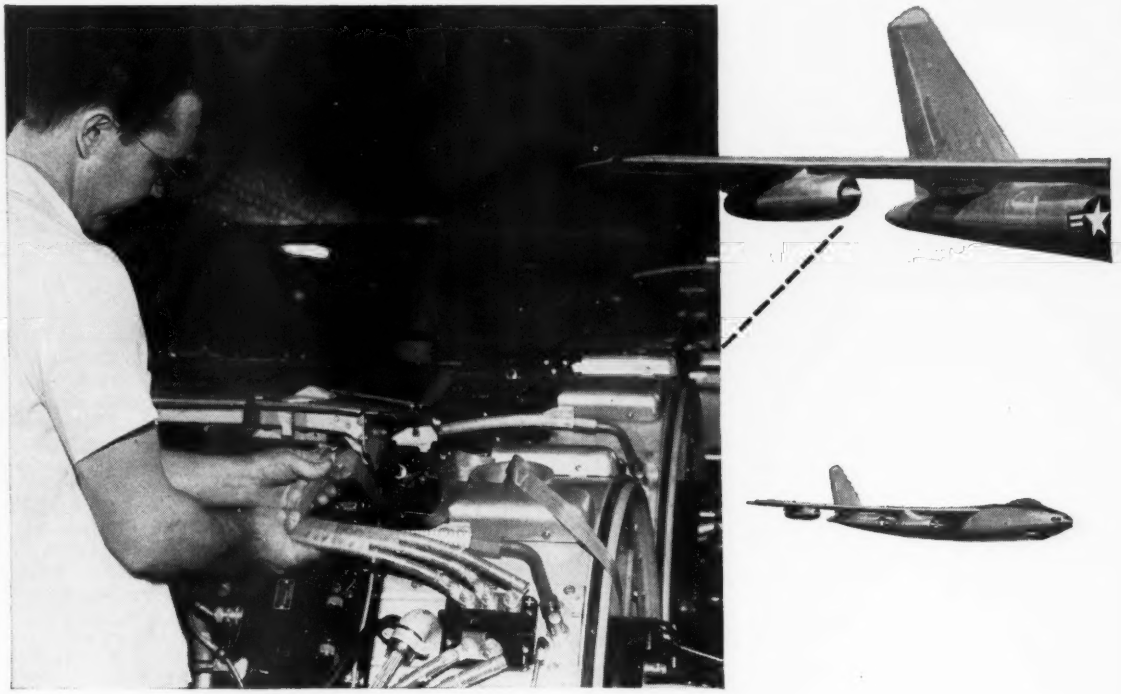

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MECHANISMS & LINKAGES

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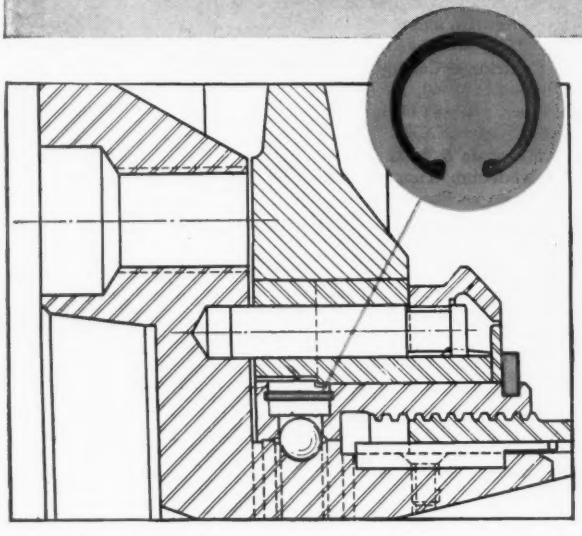

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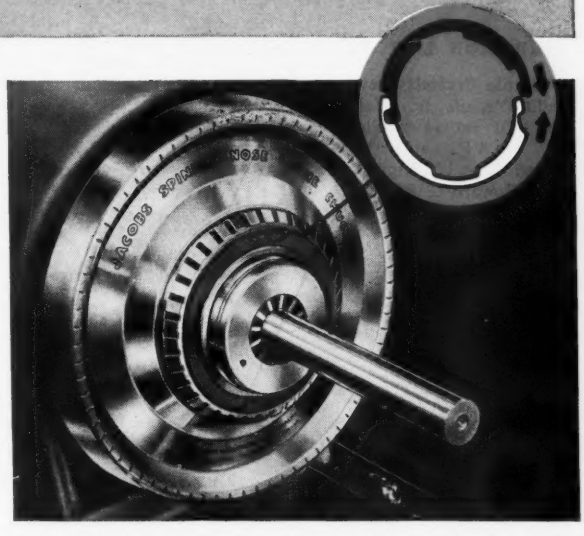

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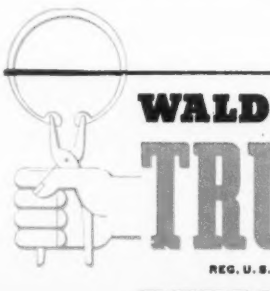

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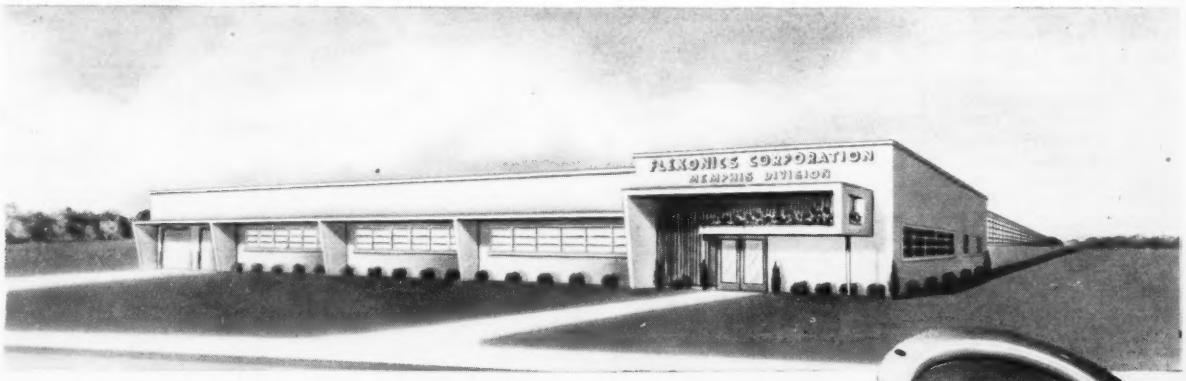

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Heat Conduction in the Region Bounded Internally by an Elliptical Cylinder and an Analogous Problem in Atmospheric Diffusion. C. J. Tranter. *Quarterly Journal of Mechanics and Applied Mathematics*, Vol. 4, Part 4, December, 1951, pp. 461–465, illus. 3 references.

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Navigation (29)

Some Factors in the Future of Air Navigation. Edward Warner. *Institute of Navigation, Journal*, Vol. 3, Nos. 1, 2, September–December, 1951, pp. 17–23.

Analysis of air navigation problems which is based on the specifying of optimum, though presently unattainable, air traffic conditions for which more efficient navigation methods must be developed. This approach is applied to the problems of air traffic control and aviation meteorology.

Astronomical Formulae for Use in Navigation. Charles Fox. *Institute of Navigation, Journal*, Vol. 3, Nos. 1, 2, September–December, 1951, pp. 12–15, illus.

Lunar Parallax Method of Astro Navigation. J. S. Thompson. *Institute of Navigation, Journal*, Vol. 3, Nos. 1, 2, September–December, 1951, pp. 50–57, illus. 1 reference.

Design, components, and operation of an instrument for automatic guidance of long-range surface-to-surface missiles which is based on the measurement of the change in position of the moon relative to the stars due to the motion of the missile over the earth's surface; inaccuracies in the system; a correction to compensate for the change in missile attitude during flight; optical elements of the stellar and lunar telescopes.

A Periscopic Sextant. *The Engineer*, Vol. 192, No. 5003, December 14, 1951, pp. 776, 777, illus.

Design and operation of a periscopic air sextant that has its index prism protruding through the air frame and sealed against flight pressure differences. The sextant incorporates an integrating mechanism with which the mean altitude of the celestial body can be determined.

Transpolar Celestial for High Speed Navigation. Thoburn C. Lyon. *Institute of Navigation, Journal*, Vol. 3, Nos. 1, 2, September–December, 1951, pp. 29–33, illus.

A celestial computer that consists of a chart of the polar area on a stereographic projection; the circles of position for the stars, sun, moon, and planets are represented on the projection by circles. Two templates for the bodies observed are fitted onto the chart; the intersection of the curves that represent the observed altitudes is the position of the aircraft.

Ordnance & Armament (22)

Aircraft Fire Control. John F. Babcock. *Ordnance*, Vol. 36, No. 190, January-February, 1952, pp. 581, 582, illus. Problems in the development and maintenance of fire-control equipment for high-speed, high-altitude aircraft.

Rockets of the Navy. W. H. Keighley. *Ordnance*, Vol. 36, No. 190, January-February, 1952, pp. 577, 578, illus. Development of aircraft rockets.

Personal Flying (42)

Gas Turbines Necessary for Small Aircraft Progress. C. V. Bachle. *Automotive Industries*, Vol. 106, No. 1, January 1, 1952, pp. 46–49, illus. Comparison of performance characteristics of piston and jet engines for personal aircraft.

Photography (26)

New Resolving Power Test Chart. *U.S., National Bureau of Standards, Technical News Bulletin*, Vol. 36, No. 1, January, 1952, pp. 8, 9, illus. 3 references. A variable-contrast test chart for measuring the resolving power of photographic lens in an aerial camera.

A Repetitive Spark Source for Shadow and Schlieren Photography. G. K. Adams. *Journal of Scientific Instruments*, Vol. 28, No. 12, December, 1951, pp. 379–384, illus. 11 references.

Basic principles, circuits, and components of the adaptation of standard radar circuits to two methods of producing repetitive sparks of high intensity and short duration. The first method, for producing superimposed photographs on a stationary film, gives four to eight discharges at individually determined time intervals of 10 μsec. or greater with an error of less than 1 μsec. The second, used with a rotating drum or mirror camera, gives a large number of light pulses at preset repetition frequencies up to 10,000 per sec. Effective photographic duration of each spark is less than 1 μsec.

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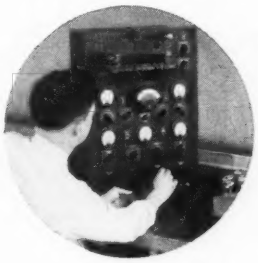

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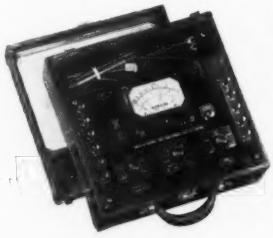

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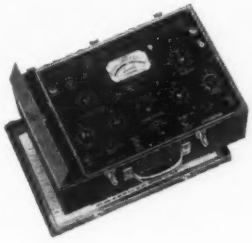

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Colour in the Wind-Tunnel. D. W. Holder and R. J. North. *The Aeroplane*, Vol. 82, No. 2111, January 4, 1952, pp. 16–19, illus.

Multicolored images of the flow about airfoils at supersonic speeds are obtained with modified Toepler and direct-shadow schlieren systems. Details of optical components, light sources, and photographic techniques are explained briefly.

Electronic Flash Photography. R. L. Aspden. *Aircraft Engineering*, Vol. 23, No. 274, December, 1951, pp. 354–360, illus. Applications of electronic flash photographic techniques to the development, instrumentation, and operation of aircraft.

New British Tube for High-Speed Photos. *Electronics*, Vol. 25, No. 2, January, 1952, pp. 218, 220, 222, illus. Development of the Mullard image converter high-speed photography tube.

The Polaroid-Land Process As Applied to Photo-Recording. *The Oscillographer*, Vol. 12, No. 4, October–December, 1951, pp. 8, 9, 12. 2 references. Explanation of the Polaroid-Land photographic process and of techniques and equipment for applying it to photorecording.

Power Plants

Reciprocal Recompression May Be Solution to High Fuel Consumption of Turbines. A. Craigon. *Canadian Aviation*, Vol. 25, No. 1, January, 1952, pp. 22, 24, 26, 56, 58, illus.

Analysis of the design and the expected performance of a gas-turboprop engine that contains a radial reciprocating recompressor. The recompressor is of the horizontally opposed piston "barrel type."

Napier Nomad. Paul H. Wilkinson. *Aviation Age*, Vol. 17, No. 1, January, 1952, pp. 40, 41, illus.

Design and performance of the Napier Nomad heavy-duty type diesel aircraft engine. A highly supercharged two-cycle diesel drives a centrifugal compressor and one-half of a contrarotating propeller; a gas turbine, for which the diesel serves as a gas generator, drives an axial-type compressor and the other half of the contrarotating propeller.

Aero-Engine Oil Systems for Cold Climates. N. Sharp. *Aircraft Engineering*, Vol. 23, No. 274, December, 1951, pp. 368–372, illus.

A study, based on service experience and cold chamber test data, of the principal causes of engine failure during starting and the means of improving the performance of oil systems in arctic weather conditions; design techniques for reciprocating-engine oil tanks for use with dilution; problems in the use of oil dilution for gas-turbine engines.

JET & TURBINE (5)

Turbines for Take-Off Assistance. *The Aeroplane*, Vol. 82, No. 2112, January 11, 1952, p. 48, illus. Practical applications of small gas turbines for take-off and climb assistance.

Gas Turbines Necessary for Small Aircraft Progress. C. V. Bachle. *Automotive Industries*, Vol. 106, No. 1, January 1, 1952, pp. 46–49, illus. Comparison of performance characteristics of piston and jet engines for personal aircraft.

British Holding Jet Lead. Paul H. Wilkinson. *Aviation Age*, Vol. 16, No. 6, December, 1951, pp. 36–38, illus. Status of British gas-turbine development and production.

Air Research Extends Gas Turbine Field. George L. Christian. *Aviation Week*, Vol. 56, No. 3, January 21, 1952, pp. 48–50, 52, 53, illus. Gas-turbine power plants for auxiliary power for aircraft pneumatic systems; units now under production at AiResearch Manufacturing Co.; applications.

Engineering the Cutlass Afterburner. *Aviation Week*, Vol. 56, No. 4, January 28, 1952, pp. 23, 24, 26, 28, 30, 31, 35, illus. Development, design, and operation of the afterburner for the Chance Vought F74-1 Cutlass; operation of the afterburner control; mounting considerations.

Boosting Gas Turbines. W. T. Gunston. *Flight*, Vol. 61, No. 2242, January 11, 1952, pp. 36–38, illus. 5 references.

Use of water injection as a means of increasing power output of gas-turbine engines; properties of possible coolants (injectants); conditions under which water-injection is advantageous.

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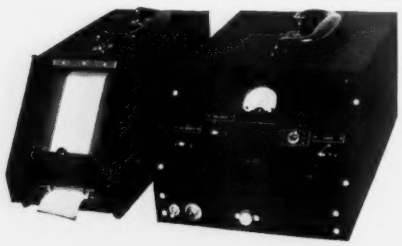

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Experiments with Gas Turbines. Alfred Barbezat. (*Die Turbine*, Vol. 5, pp. 305–312, 1909.) *Cornell Aeronautical Laboratory, Inc., Report No. CAL-38*, March, 1951. 22 pp., illus.

Investigation of the performance characteristics of two early experimental types of gas-turbine engines: the 2-hp. explosion turbine built by de Karavodine in Paris, and a 100-hp. steady flow turbine developed by the Société Anonyme des Turbomoteurs in Paris.

Turbine Starting; Mk. 3 Plessey Starter for (Rolls-Royce) Nene 4 Turbojet. *Flight*, Vol. 60, No. 2240, December 28, 1951, p. 815, illus.

Instrumentation for Aircraft Gas Turbine Development. R. E. Gorton and B. E. Miller. *S.A.E., Annual Meeting, Detroit, January 14–18, 1952, Preprint No. 730.* 32 pp., illus. 2 references. Test-cell instrumentation for mechanical problems of gas-turbine development; air and fuel instruments.

Vibration Failures. E. Colston Shepherd. *Machine Design*, Vol. 23, No. 12, December, 1951, pp. 157–160, 208, illus.

Apparatus and techniques developed by Rolls-Royce Ltd. for detecting, identifying, recording, and analyzing the vibration responsible for failure in gas-turbine buckets in flight; test results and design applications.

RAM-JET & PULSE-JET

Determination of Ram-Jet Combustion-Chamber Temperatures by Means of Total-Pressure Surveys. I. Irving Pinkel. *U.S., N.A.C.A., Technical Note No. 2526*, December, 1951. 10 pp., illus., folding chart. 1 reference.

Development of a method that determines the temperature of ram-jet combustion-chamber-outlet gases from a chart of the known factors of pressure loss across the combustion chamber, the air flow, and the total temperature and total pressure of the air at the combustion-chamber inlet. Computations made by this method are compared with those determined by thermocouple measurements from wind-tunnel tests of a 20-in. ram jet over a range of pressure altitude from 6,000 to 15,000 ft.

Escopette Pulsejet; Its Background, History, and Working Principle. *Flight*, Vol. 61, No. 2244, January 25, 1952, pp. 101, 102, illus.

RECIPROCATING (6)

Aviation Spark Plug Fouling—Its Cause and Control. V. E. Yust and E. A. Droegemueller. *S.A.E., Annual Meeting, Detroit, January 14–18, 1952, Preprint No. 729.* 21 pp., illus. 2 references.

Superchargers and Their Comparative Performance. W. T. von der Nuell. *S.A.E., Annual Meeting, Detroit, January 14–18, 1952, Preprint No. 708.* 39 pp., illus. 20 references.

A Proven Combination. *The Aeroplane*, Vol. 82, No. 2114, January 25, 1952, pp. 102–107, illus., cutaway drawings. Performance and installation of the Alvis Leonides power plants in the Percival Prince and Provost aircraft.

Higher Oil Temperatures in Aircraft Piston Engines. D. M. Harris, F. R. Watson, T. Frame-Thomson, and D. C. McMacken. *SAE Journal*, Vol. 59, No. 12, December, 1951, pp. 28–36, illus. (Excerpts from a paper: Flight Research Experience with Higher Engine Oil Temperatures.)

A New Treatment of the Tuned Absorber with Damping. D. C. Johnson. *The Aeronautical Quarterly*, Vol. 3, Part 3, November, 1951, pp. 182–192, illus. 3 references.

Study of the design of the damped tuned vibration absorber for engine crankshafts, using a three-dimensional admittance diagram; comparison with algebraic analysis; extension of method to other problems.

The Bifilar Pendulum for the Damping of Torsional Vibrations. I. L. Devaux. (*Revue Universelle des Mines*, 9th Series, Vol. 7, No. 8, August, 1951, pp. 237–250.) *Engineers' Digest*, Vol. 12, No. 12, December, 1951, pp. 403–406, illus.

The Sarazin type of bifilar pendulum damper for suppressing harmonics of various orders in engine systems. The vibration of a main system coupled to a freely vibrating "dynamic absorber" is analyzed for cases in which the absorber system has a constant natural frequency and where its frequency is proportional to the exciting frequency. The behavior of the absorber is studied in detail, and a formula is presented for its design.

ROCKET (4)

Snarler. *Hawker Siddeley Review*, Vol. 4, No. 4, December, 1951, pp. 90, 91, illus. Performance, specifications, and construction details of the Armstrong Siddeley rocket motor.

Rocket Propellants. John D. Clark. *Ordnance*, Vol. 36, No. 190, January-February, 1952, pp. 661–663. Physical properties of an ideal rocket propellant.

Production (36)

Metals and Nonmetals Joined Efficiently by Stitching. Arthur G. Denne. *Materials & Methods*, Vol. 34, No. 6, December, 1951, pp. 76–79, illus. The metal-stitching process: advantages and limitations; strength of stitched joints; applications.

Metlbond Process for Joining Metal with Adhesives. G. G. Havens and E. P. Carmichael. *Automotive Industries*, Vol. 105, No. 12, December 15, 1951, pp. 48, 49, 102, 104, 106, 108, illus.

Physical and chemical factors, advantages and disadvantages, and techniques employed in the use of Narmco, Inc.'s Metlbond process that applies organic materials in thin glue-line form to attain strength in joints.

Centrifugal Casting of Ferrous Metals. C. K. Donoho. *SAE Journal*, Vol. 60, No. 1, January, 1952, pp. 60–67, illus. 5 references. Report of the S.A.E. Iron and Steel Technical Committee, Division XXXI.

Planning the Air Force Heavy Press Program. II—50,000 Ton Press Ordered. K. B. Wolfe. *Steel Processing*, Vol. 37, No. 12, December, 1951, pp. 610–613, illus.

Blade Manufacture; Problems of Design-Form, Cost and Production; Merits of the Forged Blade. V. N. Butler. *Aircraft Production*, Vol. 14, No. 159, January, 1952, pp. 19, 20.

A Comparison of Heating Methods for Brazing. I. Lester F. Spencer. *Steel Processing*, Vol. 37, No. 12, December, 1951, pp. 617–623, illus.

Machined Aerofoils. *Aircraft Production*, Vol. 14, No. 159, January, 1952, p. 36, illus. Armstrong-Whitworth Aircraft, Ltd.'s development of an experimental machined panel with integral, spanwise stringers.

Special Machine Punches Slots in Jet Engine Shroud Rings. *Automotive Industries*, Vol. 106, No. 2, January 15, 1952, pp. 54, 112, illus.

Hydraulically operated automatic piercing machine, built by Danly Machine Specialties, Inc., Cicero, Ill., punches 80 slots in a stainless steel alloy jet-engine shroud ring in less than 5 min.

Machining Small Rotors; Special-Purpose Equipment for Automatic Generation of Blade-Profiles. *Aircraft Production*, Vol. 14, No. 159, January, 1952, pp. 2–5, illus.

Automatic Riveter Speeds Plane Assembly. *Aviation Week*, Vol. 55, No. 26, December 24, 1951, pp. 34, 35, illus. Operation of the General Drivmatic Riveter that presses 22 rivets per min. at North American Aviation, Inc.

(de Havilland) Comet Assembly. I—Ground-Level Fixtures; Centre-Section and Stub-Wing Drilling. *Aircraft Production*, Vol. 14, No. 159, January, 1952, pp. 6–16, illus.

Weighing the (Saunders-Roe) Princess. P. B. Hoskin. *The New Slipway*, Vol. 2, No. 6, December, 1951, pp. 6–9, illus. Weighing method, using portable B.O.A.C. hydrostatic weighing units, for trial and final weighing of the Princess flying boat.

Convair Set To Turn Out B-60 on B-36 Line. Irving Stone. *Aviation Week*, Vol. 56, No. 2, January 14, 1952, pp. 48–50, 52, 56, illus. Plans at Convair for producing the 8-jet B-60 aircraft on the assembly line that is used for B-36 production; 72 per cent of the B-60's parts are identical with those of the B-36.

Plastic Tooling Cuts Costs at Lockheed; Dies of Non-Critical Phenolic Resin Base Save Time by Eliminating Need for Grinding and Polishing. *Aviation Week*, Vol. 56, No. 1, January 7, 1952, pp. 42–44, 47, 48, illus.

U.S. Optical Tooling Instruments Shown. *Aviation Week*, Vol. 55, No. 25, December 17, 1951, p. 39, illus. Application of the optical tooling system to checking the alignment of tooling docks and assembly tools fabricated in them, as demonstrated by Convair and Republic.

Propellers (11)

Supersonic Propellers. W. F. Hilton. *Royal Aeronautical Society, Journal*, Vol. 55, No. 492, December, 1951, pp. 751–761, illus. 3 references.

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Investigation of the NACA 4-(5)(08)-03 and NACA 4-(10)(08)-03 Two-Blade Propellers at Forward Mach Numbers to 0.725 to Determine the Effects of Camber and Compressibility on Performance. James B. Delano. **(Two-Blade Propellers at High Forward Speeds in the NACA 8-Foot High-Speed Tunnel. III—Effects of Camber and Compressibility, NACA 4-(5)(08)-03 and NACA 4-(10)(08)-03 Blades.** James B. Delano. *U.S., N.A.C.A., Advance Confidential Report No. L5F15,* 1945, *Declassified.) U.S., N.A.C.A., Report No. 1012,* 1951. 31 pp., illus. 3 references. Superintendent of Documents, Washington. $0.30.

The Effects of Reynolds Number on the Application of NACA 16-Series Airfoil Characteristics to Propeller Design. Harold E. Cleary. *U.S., N.A.C.A., Technical Note No. 2591,* January, 1952. 15 pp., illus. 4 references.

Reference Works (47)

A Directory of Suppliers for Canada's Aviation Industry. *Aircraft,* Vol. 13, No. 12, December, 1951, pp. 38–87. Suppliers are listed alphabetically under 197 headings of products supplied; company addresses are listed alphabetically.

Rotating Wing Aircraft (34)

Some Effects of Varying the Damping in Pitch and Roll on the Flying Qualities of a Small Single-Rotor Helicopter. John P. Reeder and James B. Whitten. *U.S., N.A.C.A., Technical Note No. 2459,* January, 1952. 23 pp., illus. 3 references.

1951 Fifth Annual Rotary Wing Pictorial Review. *American Helicopter,* Vol. 25, No. 1, December, 1951, pp. 11–20, illus. Photographs and specifications of U.S. and foreign rotating-wing aircraft.

Bristol Type 171 Sycamore H.C. Mk. 10 and H.C. Mk. 11 Helicopters, England. *The Aeroplane,* Vol. 81, No. 2110, December 28, 1951, pp. 812, 813, illus., cutaway drawings.

Bristol Type 171 (Sycamore Mk. 10) Ambulance Helicopter, England. M. Berry. *American Helicopter,* Vol. 24, No. 12, November, 1951, pp. 12, 13, 16, illus.

Doman LZ-5 Four-Six Place Helicopter. *Aviation Week,* Vol. 56, No. 1, January 7, 1952, pp. 21, 22, 24, 27, illus.

McCulloch MC-4 Two-Place Tandem-Rotor Helicopter. *CEC Recordings,* Vol. 5, No. 4, December, 1952, pp. 5, 11, illus. Instrumentation for measuring and recording the complete flight characteristics of the MC-4.

S.N.C.A.S.O. SO-1120 Ariel III Jet-Powered Helicopter, France. *Aircraft Engineering,* Vol. 23, No. 274, December, 1951, pp. 376, 377, cutaway drawings.

Helicopter Prospects. *Shell Aviation News,* No. 161, November, 1951, pp. 4–6, illus.

Summary of research on costs, operation, and performance of commercial versions of single- and multi-engined military transport helicopters; prospects for commercial freight and passenger carriage.

New "Flying Vehicle" Transport in our Army. Charles W. Matheny. *American Helicopter,* Vol. 24, No. 12, November, 1951, pp. 6–11, 16, illus.

Short-haul helicopters for logistical support and tactical mobility of Army land forces; progress in development of helicopter types; data by helicopter type on capacity, speed, production status, and proposed use; limitations of the helicopter for military uses.

LAA Uses Many New Operational Methods. George L. Christian. *Aviation Week,* Vol. 56, No. 2, January 14, 1952, pp. 63, 64, 66, illus.

Modifications made by Los Angeles Airways in the basic air frame of three Sikorsky S-51 helicopters used for mail and cargo pickup and delivery; maintenance and operational methods.

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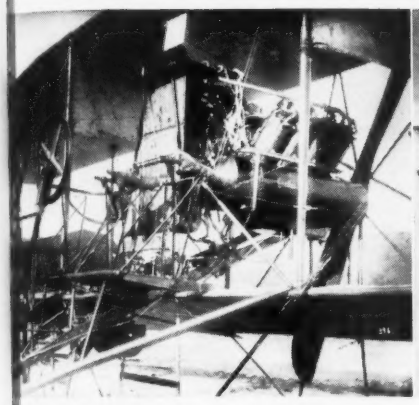

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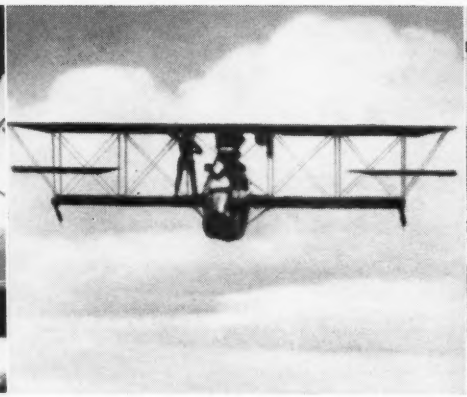
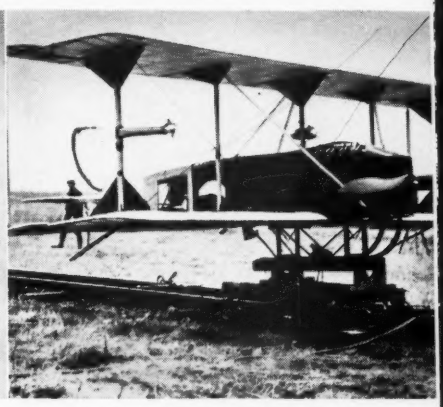
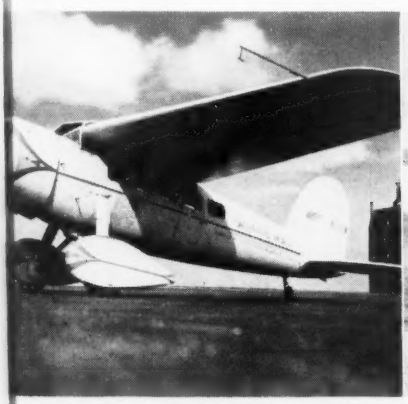


1914 Lawrence Sperry, in a public demonstration of automatic flight in Paris, 1914, won the International Safety Competition with his "stable" aeroplane.

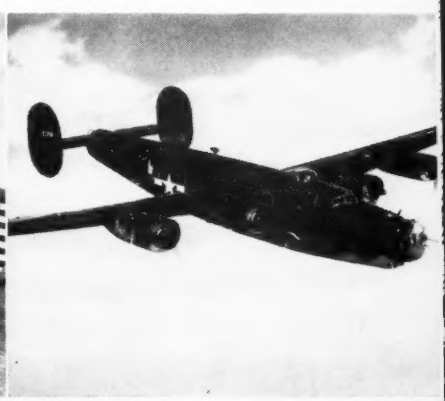


1916 Ancestor of the guided missile was the aerial torpedo developed during 1916-18 by Sperry working with the U.S. Navy. These automatically controlled "flying bombs" were tested over Great South Bay, Long Island.



1933 Automatic flight again won public acclaim in 1933 when Wiley Post made the first solo flight around the world with the Sperry automatic pilot as his "co-pilot" in the WINNIE MAE.

1937 First completely automatic landings were made by the U.S. Army Air Corps in 1937 by coupling radio aids to the Sperry automatic pilot.



1943 The first electronic automatic pilots flew thousands of B-24 s in World War II and advanced the art of precision bombing by providing an improved stable platform.

1947 The first "pushbutton" aircraft, U.S. Air Force's All-Weather Flying Division's C-54, equipped with Sperry automatic pilot and automatic approach control, crossed the Atlantic both ways in 1947 without human hands touching the controls—including take-offs and landings.

1952 The modern Gyropilot* flight control is the outgrowth of Sperry's 40 years of research, development and manufacture of automatic controls for aircraft. This versatile, all-weather pilot represents a high-performance technique for automatic control which is readily adaptable to all types of aircraft—airliners, executive craft, jets, helicopters, lighter-than-air ships and guided missiles. This technique pioneered by Sperry has led to a new fundamental concept of flight for the aircraft of tomorrow. Sperry Gyroscope Company Division of The Sperry Corporation, Great Neck, New York.

*T. M. REG. U.S. PAT. OFF.

New York Area To Get Copter Service. F. Lee Moore. *Aviation Week*, Vol. 55, No. 25, December 17, 1951, pp. 79–81, 83, illus. New York Airways' plans for passenger helicopter shuttle service between New York's three airports and for cargo-mail service from airports to Manhattan and the suburbs.

Helicopter History; Patents Reviewed; Early Work on Jet Drives. I, II. L. H. Hayward. *Flight*, Vol. 61, Nos. 2243, 2244, January 18, 25, 1952, pp. 66, 67; 92, 93, illus.

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On the Background of Pulse-Coded Computors. I. T. J. Rey. *Electronic Engineering*, Vol. 24, No. 287, January, 1952, pp. 28–32, illus. 18 references.

Outline of computer principles; organization and storage systems of digital computers; explanation of the binary system of numbers; representation of positive and negative numbers.

How Modern Computing Machines Can Help the Engineer. I—The Use of High Speed Computing Machinery in Aircraft Engine Design. Karl E. Fransson. **II—Use of Automatic Computing Equipment at Allison Division of General Motors.** J. T. Horner. **III—Use of Digital Computing Equipment in Propeller Design.** F. B. Stulen and J. A. DeVries. **IV—Application of Analog Techniques to Control Design for Aircraft Engines.** W. C. Schaffer. *S.A.E., Annual Meeting, Detroit, January 14–18, 1952, Preprint No. 735.* 26 pp., illus.

Organization of a Computer Center. F. P. Cozzone. *Product Engineering*, Vol. 23, No. 1, January, 1952, pp. 136–141, illus.

Use of the automatic computing machinery in aircraft design and analysis; types of computers and their specific applications; organization of computer facilities, including scheduling, personnel and space requirements, and costs. Five computer types are classified according to their adaptability to different types of aircraft design problems.

On the Numerical Solution of the Dirichlet Problem for Laplace's Difference Equation. J. B. Diaz and R. C. Roberts. *Quarterly of Applied Mathematics*, Vol. 9, No. 4, January, 1952, pp. 335–360. 10 references.

Proof of the convergence of three iterative methods for the numerical solution of the difference equation boundary-value problem that is analogous to the classic Dirichlet problem for the Laplace differential equation.

A Special Type of Group Displacement for Use in the Relaxation Technique. R. H. Wood. *Quarterly Journal of Mechanics and Applied Mathematics*, Vol. 4, Part 4, December 1951, pp. 432–438, illus. Special group displacements for the elimination of a single residual without introducing new residuals at the immediately surrounding points.

Graded Nets in Harmonic and Biharmonic Relaxation. D. N. de G. Allen and S. C. R. Dennis. *Quarterly Journal of Mechanics and Applied Mathematics*, Vol. 4, Part 4, December, 1951, pp. 439–443, illus. 2 references.

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Vibration Nomograph. George F. Forbes. *Product Engineering*, Vol. 22, No. 12, December, 1951, p. 201.

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Development of Auxiliary Cyclotron Equipment for Using Tritium As Bombarding Particles in a Cyclotron. D. N. Kundu, F. G. Boyle, and M. L. Pool. *U.S., N.A.C.A., Technical Note No. 2573*, December, 1951. 19 pp., illus. 3 references.

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Minimum Satellite Vehicles. K. W. Gatland, A. M. Kunesch, and A. E. Dixon. *British Interplanetary Society, Journal*, Vol. 10, No. 6, November, 1951, pp. 287–294, illus. Comparative analysis of the performance of four types of satellite vehicles; present applications; problem of obtaining a source of power to operate the instruments in the missiles.

The Importance of Satellite Vehicles in Interplanetary Flight. Wernher von Braun. *British Interplanetary Society, Journal*, Vol. 10, No. 6, November, 1951, Supplement, pp. 237–244. 1 reference.

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Analysis of the predicted performance of a nuclear-powered rocket that uses an electrically accelerated ion beam to obtain a gas ejection velocity of 100 km. per sec. The rocket would be capable of traveling from a circular orbit about the earth to a circular orbit about another planet in our solar system but is not capable of a landing or a take-off from any planet.

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Power Sources for Orbital Rockets. L. J. Grant, Jr. *Journal of Space Flight*, Vol. 3, No. 9, November, 1951, pp. 1–3. Output, structure, and efficiency considerations; qualitative analysis of radioactive and solar power sources.

Meteoric Collision Factor in Space Ship Design. Fred L. Whipple. *Aviation Age*, Vol. 16, No. 6, December, 1951, pp. 25, 126, illus. (Based on a paper presented at First Annual Symposium on Space Travel, New York, October 12, 1951.)

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Flight in the Aeropause. Randolph Hawthorne. *Aviation Age*, Vol. 16, No. 6, December, 1951, pp. 29–31, illus. 37 references. Summary of physical and physiological effects of space flight at distances greater than 12 miles above the earth's surface.

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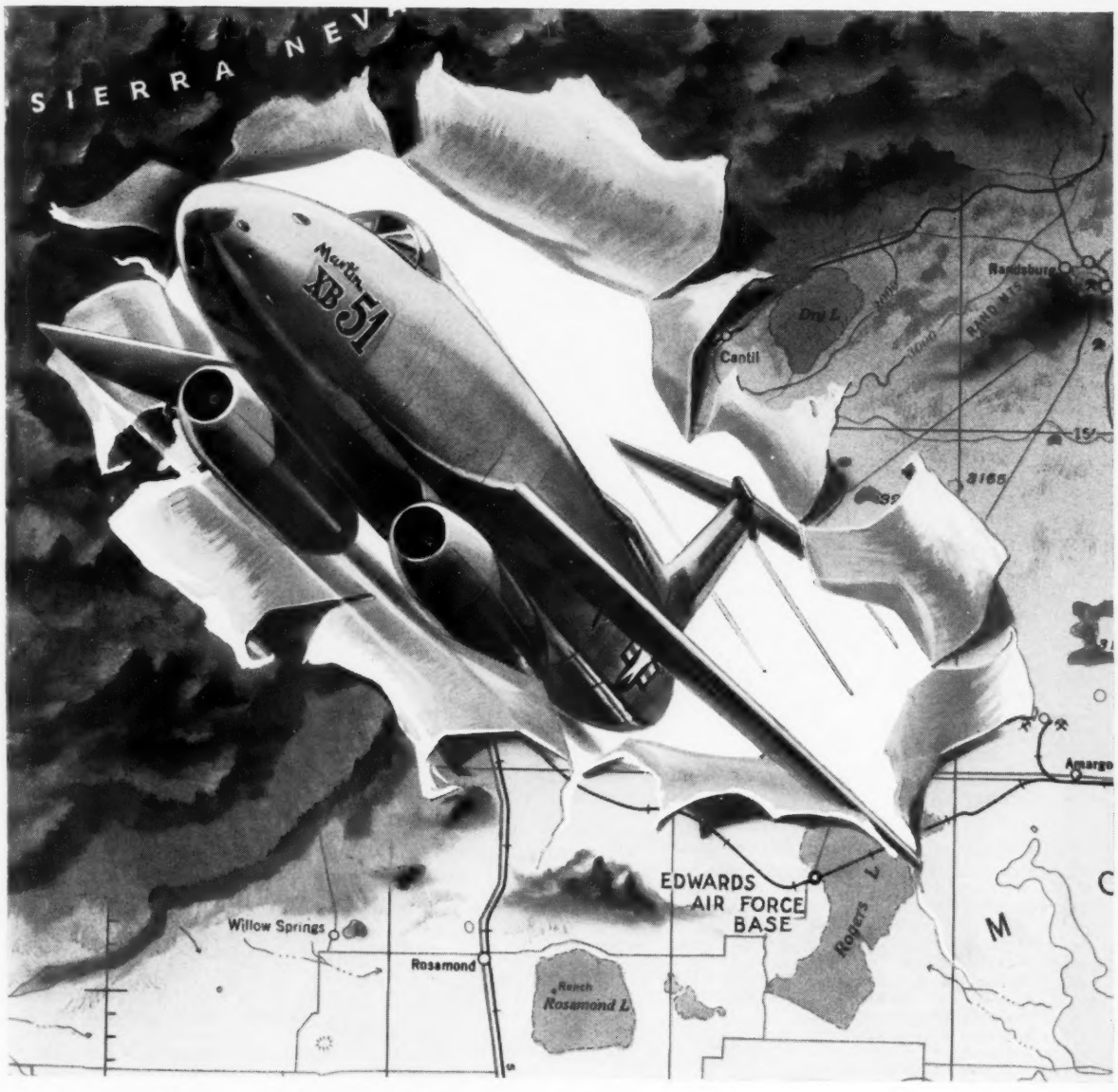

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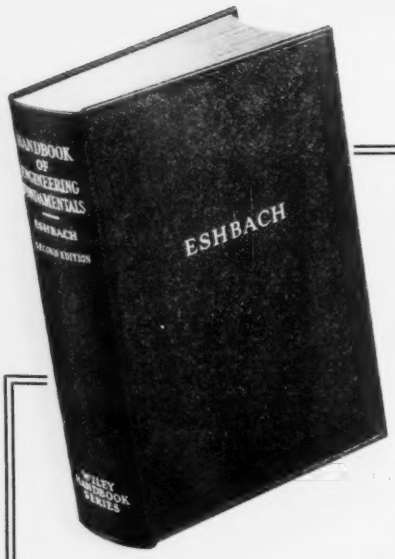

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An Acceleration-Deceleration Meter Design. Michael Conley. *Journal of Space Flight*, Vol. 3, No. 10, December, 1951, pp. 4, 5, illus. Design and operation of a meter calibrated to register plus or minus changes of velocity, in earth surface-gravity units and tenths of units, up to 5*g*.

Structures (7)

The Experimental Approach to Aircraft Structural Research. P. B. Walker. (15th Wright Brothers Lecture, December 17, 1951.) *Journal of the Aeronautical Sciences*, Vol. 19, No. 3, March, 1952, pp. 145–160, Discussion, pp. 161–172, illus. 6 references.

Fundamentals of aircraft structural engineering as shown in the experimental research work at the Royal Aircraft Establishment (Great Britain); small-scale experimental methods of studying aircraft structural principles; strength-testing of complete aircraft; design of test frames and pressure-testing equipment; instrumentation; fatigue-testing procedures.

Photoelasticity and Aircraft Design. H. T. Jessop and C. Snell. *The Aeronautical Quarterly*, Vol. 3, Part 3, November, 1951, pp. 161–172, illus.

Outline of the method of photoelastic investigation of aircraft components; specimen preparation and the two-dimensional and scattered light examination techniques; evaluation of photoelasticity as an aid to effective design. The method is illustrated by the investigation of the local stress concentrations in the various design stages of the elevator hinge bracket from a Spitfire.

On the Membrane Analogy of Torsion and Its Use in Simple Apparatus. Lars Erik Zachrisson. (*Kungliga Tekniska Högskola Handlingar Nr. 44*, 1951.) *Acta Polytechnica* (*Stockholm*), No. 80 (*Mechanical Engineering Series*, Vol. 2, No. 1), 1951. 40 pp., illus. 28 references. Sw. Kr. 4:50. In English.

Experiments with an apparatus, which records immediately perceptible moment diagrams, for evaluating, by means of the soap film analogy, the torsional stress and strain of a twisted prismatic bar; comparison with theory; derivation of an equation which does not require a reference bubble across a circular hole or measurements of the soap film except at the boundary.

A Simple Method for the Approximate Computation of All the Natural Torsional Frequencies of a Member with Variable Cross-Section. Helmut Wittmeyer. *Sweden, Kungliga Tekniska Högskola, Institution för Flygteknik, Technical Note No. KTH-AERO TN 13*, September 25, 1951. 40 pp., illus. 9 references. In English.

Development of a method that uses only one quadrature and which arrives at an approximate formula for the nth eigenfrequency of a member clamped at one end. For $n = 1$, the formula gives the approximate value assumed for the fundamental frequency; for large n, it gives values in the first approximation that are asymptotically correct.

On the Non-Linear Vibration of Elastic Bars. A. Cemal Eringen. *Quarterly of Applied Mathematics*, Vol. 9, No. 4, January, 1952, pp. 361–369, illus. 7 references.

Formulation of the problem of the vibration of bars in a general form without any restrictions; solution, by the perturbation method, of the problem of the free vibration of elastic bars that have immovable hinged ends.

Design Factors for Stress Concentration; Flat Bars with Multiple Notches. A. J. Durelli, R. L. Lake, and E. A. Phillips. *Machine Design*, Vol. 23, No. 12, December, 1951, pp. 165–167, illus. 7 references.

Beams on Cross-Girders with Clamped Ends. J. M. Klitchieff. *The Aeronautical Quarterly*, Vol. 3, Part 3, November, 1951, pp. 230–237, illus. 1 reference. Equations for the bending moments of cross-girders with clamped ends.

Readers' Forum: Note on Beams and Plates. George Gerard. *Journal of the Aeronautical Sciences*, Vol. 19, No. 3, March, 1952, pp. 207, 208, illus. 2 references.

Analysis of the classification, as a beam or as a plate, of a long rectangular structural element that is loaded by pure bending along the two shorter edges and is free along the unloaded edges.

Polynomial Approximations in Plane Elastic Problems. C. A. M. Gray. *Quarterly Journal of Mechanics and Applied Mathematics*, Vol. 4, Part 4, December, 1951, pp. 444–448, illus. 3 references. Derivation of a method of solution of plane elastic problems when the Taylor's solution for the mapping function is known; resulting equations are solved by an iterative process.

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Energy Theorems and Critical Load Approximations in the General Theory of Elastic Stability. J. N. Goodier and H. J. Plass. *Quarterly of Applied Mathematics*, Vol. 9, No. 4, January, 1952, pp. 371–380, illus. 5 references.

Extended Limit Design Theorems for Continuous Media. D. C. Drucker, W. Prager, and H. J. Greenberg. *Quarterly of Applied Mathematics*, Vol. 9, No. 4, January, 1952, pp. 381–389, illus. 4 references.

Analysis of the limit design problem of a body or a group of bodies made of perfectly plastic material and subject to a completely specified loading history. The basic concepts of perfect plasticity are explained, along with a definition of the collapse of a plastic body.

A Study of Slip Formation in Polycrystalline Aluminum. Aldie E. Johnson, Jr., and S. B. Batdorf. *U.S., N.A.C.A., Technical Note No. 2576*, December, 1951. 18 pp., illus. 7 references.

Results of a micrographic investigation of the behavior of 2S-O aluminum alloy in tension undertaken to assess the relative validity of the contradictory assumptions of slip-formation theories and their common assumption that slip is the mechanism of plastic deformation; chart of assumptions.

Readers' Forum: Comments on "Shear Center for Thin-Walled Open Sections Beyond the Elastic Limits" by G. H. Handelman. Herbert R. Lissner. *Journal of the Aeronautical Sciences*, Vol. 19, No 3, March, 1952, p. 214. 1 reference.

Thermal Stresses in a Rotating Elastic Solid of Revolution. C. E. Iliffe. **Introduction.** A. T. Bowden. *The Engineer*, Vol. 192, No. 5005, December 28, 1951, pp. 835, 836, illus. 2 references.

Derivation of a method of calculating the thermal stresses in an elastic solid of revolution of the most general shape. The method consists of adding steady-state thermal stress terms to Southwell's expressions for the stresses and boundary conditions, while retaining unchanged Southwell's governing equations for the stress functions.

On the Angular Distribution of Slip Lines in Polycrystalline Aluminum Alloy. John M. Hedgepeth, S. B. Batdorf, and J. Lyell Sanders, Jr. *U.S., N.A.C.A., Technical Note No. 2577*, December, 1951. 18 pp., illus. 6 references. An attempt to experimentally verify the assumptions involved in formulating the slip theory of plasticity.

Differentiations of Fourier Series in Stress Solutions for Rectangular Plates. A. M. Winslow. *Quarterly Journal of Mechanics and Applied Mathematics*, Vol. 4, Part 4, December, 1951, pp. 449–460, illus. 4 references.

The Circular Plate with Eccentric Hole. Samuel D. Conte. *Quarterly of Applied Mathematics*, Vol. 9, No. 4, January, 1952, pp. 435–440, illus. 5 references. Development of a solution to the problem of a thin, uniform plate bounded by two circles, one of which is interior to and eccentric to the other.

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An Analysis of an X-Ray Absorption Method for Measurement of High Gas Temperatures. Ruth N. Weltmann and Perry W. Kuhns. *U.S., N.A.C.A., Technical Note No. 2580*, December, 1951. 35 pp., illus. 5 references.

Theoretical and experimental investigation of the factors involved in the X-ray absorption method of measuring the temperature of gaseous combustion products; evaluation of design features for eliminating errors in a temperature X-ray absorption instrument; comparison of measurements obtained with the instrument with theoretical predictions.

Spark Ignition of Flowing Gases. II—Effect of Electrode Parameters on Energy Required To Ignite a Propane-Air Mixture. Clyde C. Swett, Jr. *U.S., N.A.C.A., Research Memorandum No. E51J12*, December 18, 1951. 26 pp., illus. 10 references.

Heat Conduction in the Region Bounded Internally by an Elliptical Cylinder and an Analogous Problem in Atmospheric Diffusion. C. J. Tranter. *Quarterly Journal of Mechanics and Applied Mathematics*, Vol. 4, Part 4, December, 1951, pp. 461–465, illus. 3 references. Development of a formal solution for the flow of heat in the region outside an elliptic cylinder; application to the problem of atmospheric diffusion over a saturated surface.

Water-Borne Aircraft (21)

A Semiempirical Procedure for Computing the Water-Pressure Distribution on Flat and V-Bottom Prismatic Surfaces During Impact on Planing. Robert F. Smiley. *U.S., N.A.C.A., Technical Note No. 2583*, December, 1951. 28 pp., illus. 13 references.

Landing Characteristics in Waves of Three Dynamic Models of Flying Boats. James M. Benson, Robert F. Havens, and David R. Woodward. (*U.S., N.A.C.A., Research Memorandum No. L6L13*, 1947.) *U.S., N.A.C.A., Technical Note No. 2508*, January, 1952. 41 pp., illus. 4 references.

Wind Tunnels & Research Facilities

Bumblebee Program. J. E. Arnold. *Aviation Age*, Vol. 17 No. 1, January, 1952, p. 33, illus.

Facilities, testing apparatus, and scope of operations of the Ordnance Aerophysics Laboratory at Daingerfield, Texas, for missile testing. The laboratory is operated for the U.S. Navy by Convair under the technical direction of the Applied Physics Laboratory, The Johns Hopkins University.

USAF's Guided Missile Test Center. II. Richard E. Stockwell and Randolph Hawthorne. *Aviation Age*, Vol. 16, No. 6, December, 1951, pp. 40–43, illus. Launching, tracking, and control facilities of the Grand Bahama missile-testing base.

Theoretical and Experimental Investigation of Condensation of Air in Hypersonic Wind Tunnels. H. Guyford Stever and Kenneth C. Rathbun. *U.S., N.A.C.A., Technical Note No. 2559*, November, 1951. 79 pp., illus. 33 references.

Analysis of the theory of kinetics of condensation and its limitations when applied to condensation studies for a hypersonic wind tunnel, based on experimental data obtained in the M.I.T. hypersonic tunnel at $M = 7$; modification of the condensation theory to include the dependence of surface tension on the radius of curvature of the condensation nuclei.

Colour in the Wind-Tunnel. D. W. Holder and R. J. North. *The Aeroplane*, Vol. 82, No. 2111, January 4, 1952, pp. 16–19, illus.

Modification of the Toepler schlieren apparatus results in a multicolored image of the flow in which each hue corresponds to a particular density gradient of the flow. A colored image may also be obtained by modifying the direct-shadow schlieren method; in this image, the changes in illumination are approximately proportional to the rate of change of density gradient normal to the light beam. Details of the optical components, light source, and photographic techniques are explained briefly.

Instrumentation for Aircraft Gas Turbine Development. R. E. Gorton and B. E. Miller. *S.A.E., Annual Meeting, Detroit, January 14–18, 1952, Preprint No. 730.* 32 pp., illus. 2 references. Test-cell instrumentation for mechanical problems of gas-turbine engine development; air and fuel instruments.

The Experimental Approach to Aircraft Structural Research. P. B. Walker. (15th Wright Brothers Lecture, December 17, 1951.) *Journal of the Aeronautical Sciences*, Vol. 19, No. 3, March, 1952, pp. 145–160, Discussion, pp. 161–172, illus. 6 references. Techniques for aircraft structural research; testing equipment and instrumentation.

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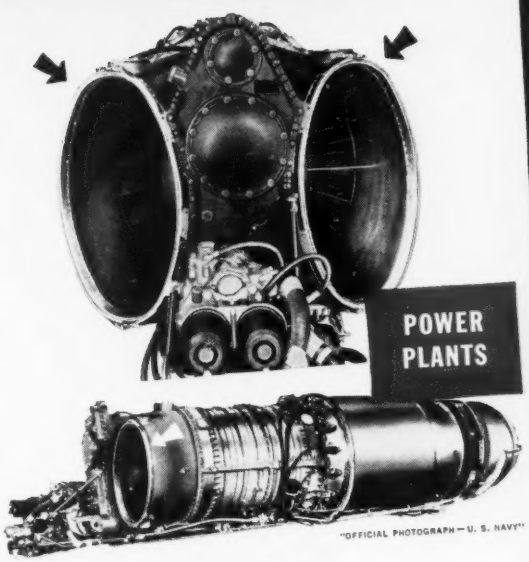

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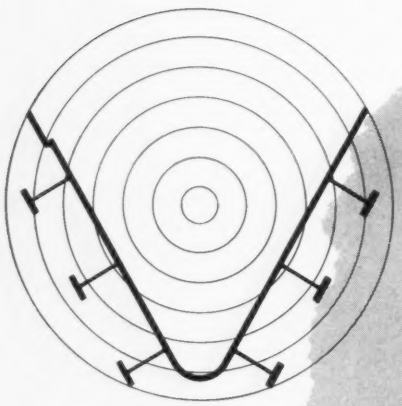

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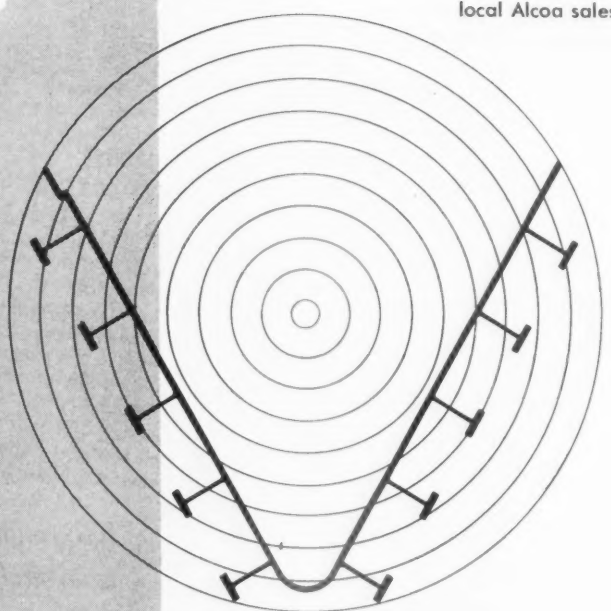

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Vibration and Shock Isolation

Charles E. Crede. New York, John Wiley & Sons, Inc., 1951. 328 pp., figs. $6.50.

This seems to be one of the first attempts to write a book on the subject of mechanical shock. It is not an easy task, for a proper discussion of the subject requires a certain amount of introductory mathematical treatment in applied mechanics. There are a number of excellent works on applied mechanics, and the opportunity to deal effectively with the subject of shock presents itself in special chapters in these well-established books.

The book contains a collection of theories and some practical applications of vibration and shock mounts, which the author prefers to call isolators. Mr. Crede also suggests the use of the term, "isolator," rather than "shock mount." There is a great deal to be said for that. Consequently, it would seem logical to talk about percentage of isolation, but he later repudiates that concept.

The formulation of mathematical equations, so essential to the student in attempting to find a solution of a problem, has in general been abridged too much and may seriously handicap the use of the book as a teaching aid. I believe it might have been advantageous to dwell more upon the analysis of the solution of the equations, which would have prevented the necessity of introducing damping into the result of an undamped problem.

The treatment of the shock problem leaves much to be desired. The separation of shock into a number of categories may lead to some confusion and may even make the problem more complex than it really is.

Considerable emphasis has been placed on the so-called velocity shock, but we should not forget that this is only one phase of the general phenomenon of shock. The concept of the cause of such velocity changes might have been broadened, in particular the infinite force that is associated with velocity shock. It also seems reasonable to ask what happens to the support after it has suddenly acquired this velocity. Unless it is a missile, the support must return to some fixed point. The time interval required for the support to return to its base, as well as the path itself, are basic parameters of shock motion. An instantaneously acquired velocity is not necessarily a shock requirement. Severe shock can be produced even if the time displacement curve exhibits a zero slope at zero time. Furthermore, it can be shown that the most damaging phase occurs after the transient is passed rather than at the moment the shock is applied. It is unfortunate that more emphasis has not been placed on this point for it might have made the book much more useful to the engineer who designs military equipment.

The author has also made generous use of amplification factors. There are some graphs that show amplification factors of 20 or more pertaining to a damped system, although, in analyzing this problem, no damping was considered. Mr. Crede is careful to point out that these values are reached only after an infinitely long time interval. In view of the transient concept of shock, it might be desirable to establish a more concrete relationship; otherwise, the reader is apt to look upon the use of these amplification factors as somewhat academic.

The author also prefers to merge the use of forces and displacements. Although this is skillfully done, I have found this to be a somewhat confusing approach in my teaching of this subject as far as the student is concerned.

The book contains a number of practical applications of shock and vibration isolations which no doubt will be appreciated by the engineer who is required to find a solution to the problem of isolating existing industrial equipment.

J. T. MULLER
Consulting Engineer

For information on I.A.S. Library Service Facilities, see page 129

Statements and opinions expressed in Book Reviews are to be understood as individual expressions and not necessarily those of the Institute.

Book Notes

AIR TRANSPORTATION

Civil Aeronautics Board Official Airline Route and Mileage Manual (Including Explanatory and Additional Material by Publisher). Part I—Domestic Section; Part II—International and Overseas Section. Washington, Compiled and Published by Air Traffic and Service Corporation, 1951. 2 Vols.; 198, 58 pp., maps. Vol. 1, $16; Vol. 2, $9.00; Set of 2 Volumes, $22.

This manual is an official publication of the Civil Aeronautics Board and is published under contract. It supersedes the C.A.B. Mileage Books, which were last revised in September, 1949. This manual delineates every certified route of all scheduled air lines of the United States operating within the United States, within United States territory, overseas, or to foreign countries. The manual lists all official airport-to-airport mileages for these routes and certain other official mileages. Other material includes: an index to all cities and other points on certified routes, references to air-line and route number; an alphabetical list of military installations and their nearest certificated point; a list of air taxi operators; over 100 maps showing all individual routes and the route systems of the larger domestic air lines; a brief article explaining route certificates and the Civil Aeronautics Act; and a table of principal definitions. Information in the manual is from official sources, and there are references to official C.A.B. actions. The book is published in loose-leaf form and is kept up to date by revised pages issued at frequent intervals.

Enplaned Airline Traffic by Community, Calendar Year, 1950. U.S., Civil Aeronautics Administration. Washington, U.S. Govt. Printing Office, August, 1951. 27 pp. $0.15.

Statistical data for domestic air-carrier traffic, international traffic, helicopter traffic, and domestic traffic of the all-cargo carriers.

ELECTRONICS

Materials Technology for Electron Tubes. Walter H. Kohl. New York, Reinhold Publishing Corporation, 1951. 493 pp., illus., diagrs., figs. $10.

The aim of this book is to present the physical characteristics of the solids used in the fabrication of vacuum tubes and to describe some of the processes for the application of these materials. The treatment is essentially nonmathematical. Material on the luminescence of solids, the treatment of gases and vapors, electron emission, and high-vacuum technique has not been included. A summary and guide to the literature of high-vacuum technique and electron emission, and several tables, are given in the last two chapters. Extensive references are given at the ends of chapters, and the author and subject indexes are comprehensive. Before publication of the book, the chapters were submitted to experts in the various fields who reviewed the material and supplied additional data. The volume should be of practical value to tube designers, development engineers, and technicians, and also to materials engi-

neers in related fields where glass, ceramics, and metals are used. The author is Consultant to the Director of Research, Collins Radio Company, which supported the work.

Contents: Chapter 1, Physics of Glass. Chapter 2, The Annealing of Glass. Chapter 3, Strain Analysis of Glass. Chapter 4, Glass-to-Metal Seals. Chapter 5, Electrical Conduction in Glass. Chapter 6, Glass in Radiation Fields. Chapter 7, Electrons, Atoms, Crystals, and Solids. Chapter 8, Tungsten. Chapter 9, Molybdenum. Chapter 10, Tantalum. Chapter 11, Nickel. Chapter 12, Copper. Chapter 13, Carbon and Graphite. Chapter 14, Joining Metals by Soldering and Brazing. Chapter 15, Ceramics and Mica. Chapter 16, Ceramic-to-Metal Seals. Chapter 17, The Phase Rule. Chapter 18, High-Vacuum Technique. Chapter 19, Thermionic Emission.

Advanced Theory of Waveguides. L. Lewin. London, Illiffe & Sons, Ltd., 1951. 192 pp., diagrs. figs. 30s.

The main purpose of this book is to expound the various methods that have been found successful in the treatment of the typical problems that arise in wave-guide work. The topics selected are representative of the field in which the microwave engineer is engaged. Many of the examples are concerned with rectangular wave guides, but the principles can be applied to most cases that are met in practice. It is assumed that the reader is familiar with the essentials of wave guides in theory and practice. Although the treatment hinges on advanced mathematics, the mathematics have been simplified wherever possible in order to make the work more widely useful. Much of the material described in this volume has arisen out of researches carried out at Standard Telecommunications Laboratories, Inc. References to original work are listed at the ends of chapters. There is also a bibliography of over 350 references which was compiled from the abstracts and references published monthly in the *Wireless Engineer* during the period from January, 1941, to June, 1951, inclusive. The references are classified under six general headings.

Contents: (1) Electromagnetic Theory and Its Application to Waveguides. (2) Cylindrical Posts in Waveguides. (3) Diaphragms in Waveguides. (4) The Tuned Post and the Tuned Window. (5) Waveguide Steps, T-Junctions and Tapers. (6) Radiation from Waveguides. (7) Propagation in Loaded and Corrugated Guides. Bibliography. Index.

Radar and Electronic Navigation. G. J. Sonnenberg. New York, D. Van Nostrand Company, Inc., 1951. 272 pp., figs. $6.00.

Described in this summary of the techniques of radar and electronic navigation for marine and air use are the Decca, Loran, and Consol systems; echo sounders; and radar for position finding and as an anticollision aid. Throughout the book, those factors are emphasized which are of practical use and importance to the navigator, without going into detailed explanations of the technical operation of the instruments. The photographs and diagrams used to explain these principles also show the navigator exactly what he may expect to see on the indicators of the apparatus under various operating conditions.

Fundamentals of Radio Communications. Abraham Sheingold. New York, D. Van Nostrand Company, Inc., 1951. 442 pp., figs. $5.25.

The subject matter of this book is presented at an intermediate level suitable for students who do not have an extensive background in mathematics or electricity. However, a sufficient amount of mathematical analysis has been included in order to develop an appreciation of the analytical techniques available for the solution of radio-circuit problems. Where the treatment of a topic has been circumscribed, references to fuller treatments are made. References to these other works are given at the ends of chapters, together with problems to be worked out by the student. The text material covers the general methods, capabilities and limitations of radio communications; the important characteristics of the basic components and circuits; and the operational features of amplitude and frequency-modulation sound-communication systems, television, facsimile, multiplex systems, radar, and Loran. The subject index is adequately detailed. The author is Associate Professor of Electronics, U.S. Naval Postgraduate School, Annapolis.

EQUIPMENT

ELECTRIC

Using the AN-"M" Connector. (Bulletin No. SIM-1.) Los Angeles, Cannon Electric Company, 1951. 30 pp., illus., diagrs.

An instruction and service manual on the installation, inspection, disassembly, and reassembly of the AN-"M" series and other Cannon Electric series having resilient inserts.

FLIGHT SAFETY

Survey of Research Projects in the Field of Aviation Safety. First Annual Supplement, January, 1952. New York, The Daniel & Florence Guggenheim Aviation Safety Center at Cornell University, 1952. 96 pp. $1.00.

This report continues the form adopted by the original survey, consolidating information on nonclassified research being conducted in various fields affecting aviation safety. This report lists additional projects on which information was obtained during 1951, including work in Canada and Great Britain. There is also a section referring to those projects that were either completed or discontinued during the year. As in the previous survey, the projects are classified under 25 major subject headings. Preceding the 94-page list of safety projects is material on the activities of the Center, safety education, and accident statistics. There are also comments on the organizations and agencies contacted, the indexing procedure, on gaps in present research, and additional research required. Given for each project are the title, a brief description of the work, the name of the sponsor and location, and a reference number

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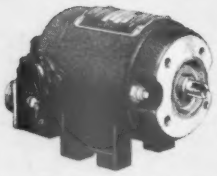

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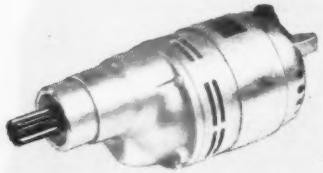

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to project sheets in the files of the Center, where additional information may be found.

MACHINE DESIGN

Engineers' Illustrated Thesaurus. Herbert Herkimer. New York, Chemical Publishing Company, Inc., 1952. 572 pp., illus. $6.00.

The 8,000 sketches and drawings describing machine parts and their movements were selected from domestic and foreign patent-office gazettes and trade catalogs. The drawings are grouped into two main divisions, statics and dynamics, which are further subdivided into classes, sections, and topics. Topics are listed on the left-hand pages, illustrations on the right. Other fields of engineering are covered in addition to mechanical engineering. The book concludes with a 14-page index of topics.

Contents: Class 1, Fasteners. Class 2, Adjusting Devices. Class 3, Supports and Structures. Class 4, Basic Mechanical Movements. Class 5, Elevators, Derrick, Cranes, Conveyors. Class 6, Transmission of Liquids and Gases. Class 7, Combustion. Class 8, Prime Movers. Class 9, Transportation. Class 10, Industrial Processes. Class 11, Electrical Appliances. Class 12, Comfort Heating, Cooling and Air Conditioning.

MATERIALS

Powder Metallurgy. (Gt. Brit., Department of Scientific and Industrial Research, Selected Government Research Reports, Vol. 9.) New York, British Information Services, 1951. 159 pp., illus., diagrs., figs. $4.25.

Contents: Report No. 1, The Surface Energies of Metals and Alloys, Based on A.R.D. Met. Report, December, 1948, by C. J. Leadbeater. Report No. 2, The Examination of Sintered Metal Components, Based on A.R.D. Met. Report, August, 1944, by L. Northcott and C. J. Leadbeater. Report No. 3, Some Properties of Engineering Iron Powders, Based on A.R.D. Met. Report, May, 1946, by C. J. Leadbeater, L. Northcott, and F. Hargreaves. Report No. 4, Production of Iron Powder by Electrodeposition, Based on A.R.D. Met. Note, March, 1947, by G. E. Gardam. Report No. 5, German Sintered Iron Bearings, Based on A.R.D. Met. Report, December, 1945, by L. Northcott and C. J. Leadbeater. Report No. 6, Trials of Sintered Iron Driving Bands for 20 mm. Oerlikon Ammunition, Based on A.R.D. Met. Report, June 1943, by L. Northcott and B. D. Burns. Report No. 7, Sintered Iron-Copper Compacts, Based on A.R.D. Met. Report, March, 1947, by L. Northcott and C. J. Leadbeater. Report No. 8, An Aluminium Alloy Made by Powder Metallurgy, Based on R.A.E. Report, by R. L. Bickerdike. Report No. 9, Notes on German Developments in Non-Carbide Powder Metallurgy (1939–1945), Based on A.R.D. Met. Report, March, 1947, by C. J. Leadbeater. Report No. 10, The Tensile Strength of Titanium at Various Temperatures, Based on R.A.E. Tech. Note, November, 1948, by R. L. Bickerdike and D. A. Sutcliffe.

Wood Aircraft Inspection and Fabrication. U.S., Munitions Board, Aircraft Committee, Subcommittee on Air Force-Navy-Civil Aircraft Design Criteria. (ANC-19.) Washington, U.S. Govt. Printing Office, April, 1951. 335 pp., illus., diagrs., figs. $1.25.

The technical material in this bulletin, which is based chiefly on results of investigations conducted during the past 40 years by the Forest Products Laboratory, is limited to information on wood, glues, and processing which is of direct concern to inspectors and fabricators of wood aircraft. Strength data and other design criteria are not included.

Contents: Chapter 1, General. Chapter 2, Wood. Chapter 3, Modified Wood. Chapter 4, Aircraft Glues. Chapter 5, Processing and Fabrication. Chapter 6, Miscellaneous: List of Specifications, Glossary, Index.

Design of Wood Aircraft Structures. U.S., Munitions Board, Aircraft Committee, Subcommittee on Air Force-Navy-Civil Aircraft Design Criteria. 2nd Ed. (ANC-18.) Washington, U.S. Govt. Printing Office, June, 1951. 234 pp., illus. diagrs., figs. $1.00.

Contents: Chapter 1, General: Nomenclature. Chapter 2, Strength of Wood and Plywood Elements: Physical Characteristics and Factors Affecting the Strength of Wood; Basic Strength and Elastic Properties of Wood, Columns, Beams, Torsion; Basic Strength and Elastic Properties of Plywood; Plywood Structural Elements; Flat Rectangular Plywood Panels; Joints. Chapter 3, Methods of Structural Analysis: General, Wings, Fixed Tail Surfaces, Movable Control Surfaces, Fuselages, Hulls and Floats, Miscellaneous. Chapter 4, Detail Structural Design: General, Plywood Covering, Beams, Ribs, Frames and Bulkheads, Stiffeners, Glue Joints, Mechanical Joints, Miscellaneous Design Details, Examples of Actual Design Details.

Sandwich Construction for Aircraft. Part 2—Materials Properties and Design Criteria. U.S., Munitions Board, Aircraft Committee, Subcommittee on Air Force-Navy-Civil Aircraft Design Criteria. (ANC-23.) Washington, U.S. Govt. Printing Office, May 1951. 101 pp., illus., diagrs., figs. $0.50.

Contents: Chapter 1, Introduction. Chapter 2, Mechanical Properties of Facing and Core Materials. Chapter 3, Isotropic Sandwich Construction. Chapter 4, Orthotropic Sandwich Construction. Chapter 5, Double-Skin Corrugation Construction. Chapter 6, Detail Design.

Strength of Metal Aircraft Elements. U.S., Munitions Board, Aircraft Committee, Subcommittee on Air Force-Navy-Civil Aircraft Design Criteria. Revised Ed. (ANC-5.) Washington,

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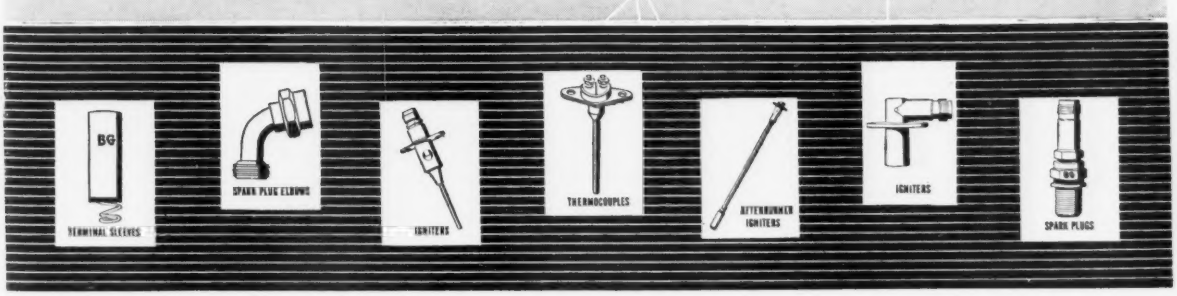

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U.S. Govt. Printing Office, June, 1951. 125 pp., figs. $0.55.

Contents: Chapter 1, General: Purpose and Use of Document, Standard Structural Symbols, Commonly Used Formulas, Basic Principles and Definitions, Types of Failures, Columns, Thin-Walled and Stiffened Thin-Walled Sections. Chapter 2, Steel: General Properties, Columns, Beams, Torsion, Combined Loadings, Joints, Parts, and Fittings. Chapter 3, Aluminum Alloys: General Properties, Columns, Beams, Torsion, Combined Loadings, Joints, Fittings, and Parts. Chapter 4, Magnesium Alloys: General Properties, Columns, Beams, Torsion, Combined Loadings, Joints, Fittings, and Parts. Chapter 5, Miscellaneous Metals: General Properties.

British Standard Mechanical Tests for Metals (Excluding Welds). (B.S. Handbook No. 13, 1951.) London, British Standards Institution, 1951. 243 pp., diagrs., figs. 17*s.* 6*d.*

This reference book for industry and colleges brings together all methods of mechanical testing established in British Standards; these standards embrace aircraft metals and light alloys at high temperature. The handbook includes also relevant extracts from other standards on mechanical testing and comparisons. Tensile, hardness, impact, ductility, creep, and transverse tests; tests on thin metal; some miscellaneous tests; testing machine verification; and conversion factors are covered.

MECHANICAL ENGINEERING

Mechanical Engineering Research, 1947–1950. (Gt. Brit., Department of Scientific and Industrial Research.) New York, British Information Services, 1951. 39 pp., illus. $0.65.

A report on facilities, work accomplished, and projects underway. Appendixes include a list of lectures on the work of the Mechanical Engineering Research Board and a list of papers published externally.

NAVIGATION

Summary Progress Report. Air Navigation Development Board. Washington, July 1, 1951. 33 pp , diagrs.

Status of the program leading to a Common System of Air Navigation and Traffic Control.

REFERENCE WORKS

British Standard Glossary of Aeronautical Terms. (B.S. 185: Part 3: 1951.) London, British Standards Institution, 1951. 70 pp. 7*s.* 6*d.*

This is the concluding portion of the revision of the *Glossary of Aeronautical Terms* (1940), of which Parts 1 and 2 have already been published. It has been extended in view of recent developments and includes sections on navigation, parachutes, air-traffic and ground services, radiocommunication and radiolocation, and meteorology. Over 500 terms are defined. Tables cover international standard atmosphere, Beaufort scale of wind force, Beaufort letters and their interpretation, code for state of the sea, and specification of swell waves. This volume also contains a combined index of the terms defined in all three parts.

Changes of Address

Since the Post Office Department does not as a rule forward magazines to forwarding addresses, it is important that the Institute be notified of changes in address 30 days in advance of publishing date to ensure receipt of every issue of the *Journal* and *Review*.

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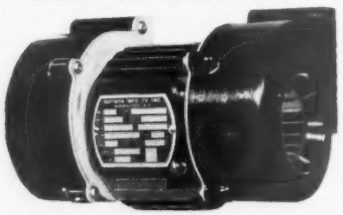

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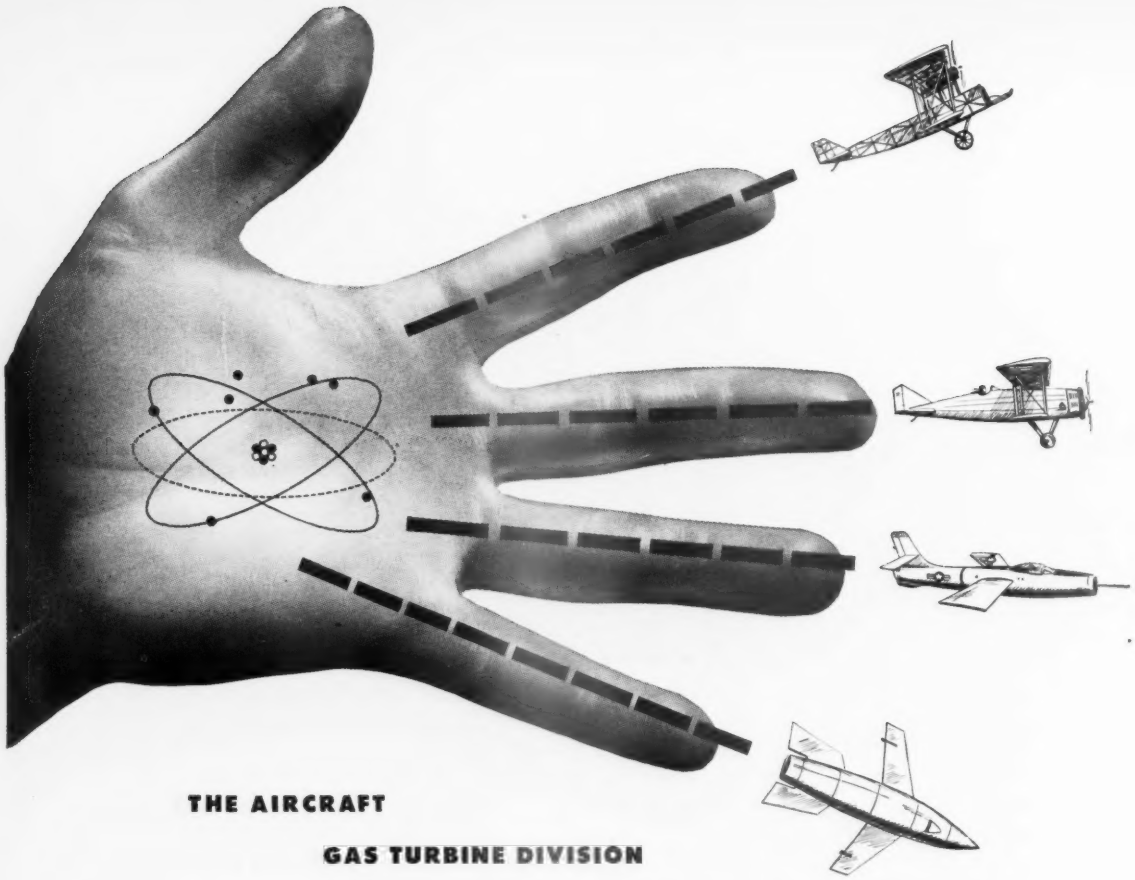

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This section is for the use of individual members of the Institute seeking new connections and organizations offering employment to Aeronautical specialists. Any member or organization may have requirements listed without charge by writing to the Secretary of the Institute.

Wanted

Professors—The U.S.A.F. Institute of Technology has several vacancies for qualified professors or engineers to teach on a graduate and undergraduate level in aeronautical, mechanical, and electrical engineering. Employment will be effected in accordance with Civil Service Regulations. Grade levels range from GS-11, $5,940 per annum, to GS-13, $8,360 per annum. Applications should be made on Standard Form 57 available at any Post Office or by Letter to the Dean, Resident College, U.S.A.F. Institute of Technology, Wright-Patterson Air Force Base, Dayton, Ohio.

Model Makers—Several openings for wind-tunnel model makers, dynamic model builders, contest model builders, or precision machinists who can do high-quality work on wind-tunnel models, guided missiles, and precision subassemblies. To carry through all operations from making of templates to hand filing of contours. Permanent employment in growing organization with chance for advancement. Excellent working conditions. Eighteen hours weekly overtime. Top wages for top men. Address replies to Aerolab Development Company, 330 West Holly Street, Pasadena, Calif.

Senior Design Engineer—For layout and detail design of research vehicle air frames, wind-tunnel equipment, etc., and other types of aerophysics research equipment. This is an excellent opportunity for a capable man to work closely with small, highly qualified engineering and experimental group in a wide variety of interesting projects. Previous experience in this particular field not essential, but must have above average intelligence and ability to carry out a project to completion, including preparation of finished drawings, reports, liaison, and expediting of his own work when necessary. Must have thorough grasp of fundamentals governing mechanics, dynamics, and stress analysis. Aerodynamics training or experience desired but not necessary. Sample material, résumé, and reference required. Address replies to Aerolab Development Company, 330 West Holly Street, Pasadena, Calif.

Aeronautical Engineers—Cornell Aeronautical Laboratory, Inc., an affiliate of Cornell University, has open positions in varying fields of the aeronautical sciences in junior, associate, and senior categories. Men with experience and interest in: high-speed aerodynamics, aircraft structures, aeroelasticity, dynamic analysis, control and stability, flight research, and wind-tunnel testing are needed. There are also several open positions in the field of operations and systems analysis. Our salary structure is the same as that found in industry. For further information, please write, referencing this notice, to P.O. Box 235, Buffalo 21, N.Y.

379. Senior Project Engineer—Wanted for work on armament, radar, aircraft, and missile systems. Good mathematics background required. Varied problems dealing with design, effectiveness, suitability, logistics, and cost. Must be capable of organizing and carrying out projects. Excellent career opportunity. Located in New Jersey, 2½ miles from New York City.

375. Engineers—Advantages of Vermont living offered by internationally known manufacturer of aeronautical equipment seeking mechanical engineers to handle production design. Plant located in small community in central section of state. Near good schools and colleges. Submit résumé and salary desired.

Available

385. Professor—Academic position with rank of Associate or Assistant Professor desired for the 1952–1953 year. Excellent qualifications with regard to academic training in engineering and mathematics, industrial experience, and published works. Specialist in flutter and vibration, rotary wing aircraft, automatic controls, and analog and digital computation. Complete details on request.

384. Mechanical Engineer—California Register. Thirteen years' experience; 2 years' teaching evening classes, Washington University, St. Louis, Mo. Supervisory experience includes 3 years Chief of Design, 1 year Project Engineer (power plant), 1 year Group Engineer (power plant), 1 year lead man (power plant and preliminary design), 2½ years as specialist in charge of prototype design on a Mach 2.75 missile. Active vendor and special warhead contacts 1946 to present. Active Wright Field and BuAer contacts 1943–1945; active C.A.A. Washington contacts 1945, 1946. Two and one-half years' flight and bench test work. Experienced in preliminary design (8 years), including practical estimations of manpower (shop and engineering) and material costs. Experienced in writing technical reports, specifications, and sales brochures. Diversified experience ranges from complete airplane and guided missile design to components, including liquid oxygen test devices, injector plates, rocket motor shells, high-speed bearing applications, miniature power plants, and optics systems for seekers. Will consider supervisory or administrative work. Will not consider routine replies. Will send detailed résumé on receipt of your outline of possibilities. Currently hold two professional GS-13 Civil Service ratings.

383. Flutter and Vibration Engineer—Bachelor and Master's degree in Aeronautical Engineering. Aggregate of 5 years of experience in dynamics field. One year at N.A.C.A. as a structural research scientist; 1 year at a leading jet aircraft manufacturer as a flutter engineer, and 3 years at a leading helicopter manufacturer as assistant chief of vibrations department, which includes design experience in vibration isolation equipment. Desires position in the New York City area.

382. Engineer—M.S. Nine years' experience in system dynamics and servomechanisms. Presently head of servo group of large aircraft company. Desires position with increased scope, New York area.

381. Project Manager and Engineer—More than 11 years' intensive experience as a project engineer and development engineer. Aptitude for organizing, planning, and executing engineering and manufacturing operations. Experience in aircraft and nonflying gas turbines, aircraft superchargers, centrifugal compressors, natural gas pipeline boosters, and flight-testing military aircraft. Much practice in dealing with customers and subcontractors.

The number preceding the notices represents the Box Number of the Institute of the Aeronautical Sciences to which inquiries should be addressed.

380. Administration Engineer—Age 29. B.S. Aero. Engrg., Iowa State College; M. B. A., Production and Personnel Management major, Northwestern University. One year aircraft maintenance supervisory experience, U.S. Navy. Four years' experience with major air-frame manufacturer; 9 months design work, 8 months training program covering both engineering and production phases of the organization, 3 years flight-test planning; emphasis on turbojet power-plant development work. Interested in production management work; however, will consider engineering or marketing opportunities, or work with air line contemplating jet operations. Available in June.

378. Senior Aeronautical Engineer—Ph.D. Five years' scientific work with well-known university, mainly on aerodynamic and structural subjects. Graduate and undergraduate teaching experience. More than 15 years' background with European companies in positions as aerodynamicist, flight-test engineer, designer, head of research and project groups. Presently employed as chief engineer and director of development department. Sound knowledge of modern high-speed design methods and experience in planning and leading development work. Desires position either with university as professor of aeronautical engineering in connection with research work or with prosperous aircraft firm as consultant or head of research or development group. Please advise as to the nature of openings in first letter and do not send routine forms.

377. Aeronautical Scientist—Specialist in hydrodynamics, aerodynamics, and gas dynamics. German Ph.D. Teaching experience in applied mathematics and mechanics; 12 years' experience with aircraft industry; about 50 publications and classified papers with results reported in textbooks by noted authors. Now in Government position; desires high-level research and development position or professorship combined with research. Offer with statement of salary range appreciated.

376. Aeronautical Engineer—B.S. degree from The Pennsylvania State College. Two years' experience as a trainee for a supervisory capacity with a large corporation, knowledge of shop practices and machinery and equipment repairs, plus good knowledge of transportation field—both passenger and freight. Age 25, veteran. Desires position with air line or aircraft manufacturer.

374. Aeronautical Engineer—Six years' experience in aerodynamic design of piloted airplanes and guided missiles; 3 years' experience in present supervisory position as aerodynamics engineer with Government flight-test agency. B.S. (Aero. Eng.), 1942. Presently taking evening graduate studies leading to M.S. degree in spring 1952.

373. Project Engineer—Mechanical. Master's Degree, registered P.E. Ten years' successful record on design and development of special machinery and instruments, 3 years' supervisory experience, specialized knowledge in fields of vibration, impact, fatigue testing, and stress analysis. Analytical ability. Several publications. Desires responsible position. Specify nature of opening in first letter.

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